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A Once and Future War 4

Seven years ago, writer-director James Cameron was an unknown entity with only an ultra-low-budget horror picture to his credit. Arnold Schwarzenegger was a world-class bodybuilder with a few less-than-world-class movies under his belt and Linda Hamilton was a young actress with a number of nondescript teen roles on her brief resume. *The Terminator* changed all that. A landmark science fiction film whose nonstop tech-action was punctuated with rare humor and an affecting love story, *The Terminator* was the impetus for major career breaks across the board. In the next half-dozen years, Cameron would become one of the hottest directors in Hollywood. Schwarzenegger would become the world's biggest boxoffice star and Hamilton would become the celebrated beauty of a cult television series. Though a sequel seemed inevitable, prospects for launching one were snarled in a spider's web of proprietary interests and legal entanglements until early 1990 when Carolco Pictures stepped in and cleared the way. Eighteen months later, after a grueling six-month shoot and an intense postproduction schedule, one of the biggest films in history was ready for release. Bringing magic to *Terminator 2: Judgment Day* was an army of effects people — most of them veterans of earlier Cameron productions. Stan Winston and company were responsible for Terminator makeups and animatronic puppetry. Dennis Muren supervised the creation of an advanced shape-shifting terminator at Industrial Light and Magic. Gene Warren of Fantasy II provided a major truck crash and a future war in miniature while Robert and Dennis Skotak of 4-Ward Productions wreaked nuclear havoc on Los Angeles. Video Image supplied 'Termovision' point-of-view material and Pacific Date Images performed some digital rescue work. The result was an epic foray into science fiction filmmaking. *Article by Jody Duncan.*

FRONT COVER — Gunshot wounds are no deterrent to the T-1000 in *Terminator 2*. The Terminator returns to protect John Connor in *Terminator 2* BACK COVER.

A ONCE AND FUTURE WAR

article by
Jody Duncan





As writer and director of *The Terminator*, fledgling filmmaker James Cameron made his mark with a science fiction thriller that earned handsome profits for its modest investment and became a cultural icon in the process. Six years later, and now one of the hottest directors in the business, he launched into a sequel destined to become one of the biggest films of all time. On location during the shooting of *Terminator 2: Judgment Day*, Cameron surveys the Los Angeles flood control channel setting selected for a major chase scene.

It is a given of the modern film industry that makers of high-grossing movies will attempt to repeat their successes and profits with one or more sequels — whether or not the original stories lend themselves to a second chapter. Indeed, some sequels of recent years have severely stretched the bounds of logic, as acknowledged by Bruce Willis' character in *Die Hard 2* when he wondered aloud — with the audience — how he could find himself in such an unlikely situation *again*.

The *Terminator*, however, seemed to be a particularly obvious candidate for the sequel treatment, in both economic and dramatic terms. Not only had the film become one of the biggest hits of 1984, reaping sizable profits and rocketing Arnold Schwarzenegger into superstar status, its ending had strongly foreshadowed a continuing story that was as compelling as the first. Sarah Connor had survived the attempt on her life by a killing machine sent from the future; yet, as credits rolled, it was clear that she was driving off to face an even greater ordeal. Before her lay the task of preparing herself and her soon-to-be-born son for *Judgment Day* — the day a self-aware and technologically superior War Machine would turn on its creators and launch a devastating nuclear assault.

Ironically, writer-director James Cameron had not written the original script with an eye toward making a sequel. With the film's tremendous success, however — and after much urging from Schwarzenegger, who longed for an opportunity to reprise the role with which he was most identified — Cameron began formulating the storyline that would conclude the *Terminator* saga, even as he went on to write and direct both *Aliens* and *The Abyss*. With rights to a *Terminator* sequel legally entangled for half a decade, it was not until early 1990 that Cameron struck a deal with Carolco Pictures to make *Terminator 2: Judgment Day*. Mandating a summer 1991 release, the Carolco deal left precious little time to bring in a major motion picture for which there was, as yet, not even a screenplay. After first securing commitments from both Schwarzenegger and *Terminator* costar Linda Hamilton, Cameron and cowriter William Wisher jumped immediately into an intense and arduous eight-week writing period, completing the script just weeks before the October start of principal photography.

Rather than rehashing the original story, the continuation centered on Sarah's son, John — now a troubled ten-year-old. Having spent his early childhood in the company of survivalists and guerrillas, John has now been separated from his mother — whose terrorist activities and rantings



A strong proponent of the sequel was Arnold Schwarzenegger, whose killer cyborg character has now been reprogrammed to protect the young son of the woman his predecessor had tried to destroy.



In the years since her first encounter with the Terminator, Sarah Connor (Linda Hamilton) has become a hardened warrior and survivalist determined to insure that her son grows up to fulfill his destiny as the savior of mankind.

of imminent nuclear disaster have landed her in a state mental hospital. Placed in the indifferent care of foster parents, John is a tough and bitter child who now uses his military-style training for nothing more productive than breaking into automatic teller machines. The veracity of his mother's doomsday prophecy is made clear to him, however, when he suddenly finds himself the ward of one *Terminator* — an '800' series model introduced in the original film — and the target of yet another. This new '1000' series terminator is the ultimate infiltration unit — a liquid metal machine capable of imitating any form with which it comes in contact. Sent by the adult John Connor to protect his ten-year-old self, the *Terminator* — who looks like an antiquated six-million-dollar man in comparison — pits himself against the technologically advanced T-1000 in a one-on-one battle that will determine the fate of mankind.

Not surprisingly, an array of animatronic effects and nearly one hundred fifty visual effects — including some of the most advanced computer graphics shots ever attempted in a film — were required to tell the ambitious story. Cameron, along with coproducers B.J. Rack and Stephanie Austin, determined that the scope of the project was far too large to be realized by a single facility. Ultimately the work was divided among four principal effects teams. Stan Winston, who had created makeup and animatronic effects for the original film, was assigned a similar, but much expanded role for *Terminator 2: Industrial Light and Magic*, under the effects supervision of Dennis Muren, took on the more than forty computer graphics shots. Gene Warren of Fantasy II, who had also contributed miniatures and opticals to the original film, did likewise on the sequel. And Robert and Dennis Skotak of 4-Ward Productions — frequent Cameron collaborators — created a realistically devastating nuclear assault on downtown Los Angeles. Additional effects support was provided by Pacific Data Image and Video Image.

In July, a hectic three-month preproduction period began in which locations were scouted, key roles were cast, and major effects sequences were designed and storyboarded. Conceptual artist Stephen Burg — who had designed the NTIs and their subaquatic vessels for Cameron's *The Abyss* — began designing additional hunter-killer machines for the vast future war sequence which was to open the new film; production designer Joseph Nemec III oversaw the construction and refurbishment of key sets, including a massive steel mill which had been abandoned for seventeen years; and effects designer John Bruno and artist Phillip Norwood labored to complete detailed storyboards depicting the film's nonstop action and effects sequences.

The effects teams, too, were engaged in heavy preproduction. ILM, in particular, had to gear up for what would be its biggest computer graphics assignment yet. Though a six-man team had sufficed for the few computer generated shots produced by the facility for *The Abyss*, the projected workload for *Terminator 2* demanded major expansion. "We hired animators and software engineers from all over the world," said effects producer Janet Healy. "They came from London, Canada, New Zealand. By the time we were done hiring, we had expanded our CG department by three times and had a crew of thirty-five people." In addition, ILM invested close to \$3 million in new equipment and hardware. "We needed a lot of high-powered equipment to generate these images," Dennis Muren asserted. "We now have eleven big Silicon Graphics machines — which are mammoth processors — as well as five middle-sized and ten small-sized ones. That's a lot of power — probably more power than a Cray supercomputer would have." Another half million dollars was invested in new software designed specifically for *Terminator 2*.

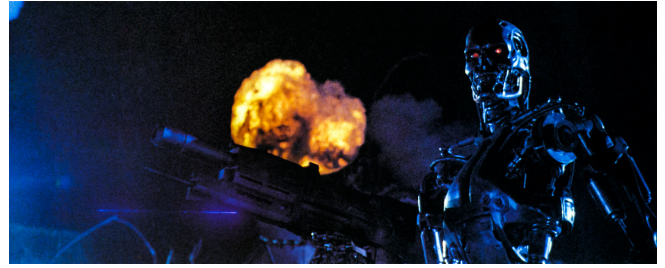


In the post-nuclear wasteland of Los Angeles in 2029, a grim battle rages between human guerrilla fighters and high-tech war machines. An expansive demolition site served as the live-action battleground. Junk cars were burned and then photographed for an establishing crane shot that was later enhanced by Fantasy II with a background miniature of a collapsed freeway overpass.



Special makeup and animatronics creator Stan Winston examines a fallen endoskeleton at the future war location.

Muren, fresh off a year's sabbatical during which he had immersed himself in the study of computer graphics technology, was more than ready to put both the new equipment and his newfound knowledge to the test. "I had started to lose interest in traditional effects," Muren admitted, "because the quality of the images you can get traditionally is limited. And, personally, I don't want to work on anything if it isn't going to be spectacular. But after our work on *The Abyss*, I became very excited about the possibilities of computer graphics. Then *Terminator 2* came along and the storyboards that Jim showed us were absolutely awesome. These effects would definitely be the next generation of CG technology."



Amidst explosions and laser fire, an impassive endoskeleton scans the battlefield for human targets. Four full-size puppets — two of which were articulated extensively with rods and cables and radio control — were manufactured by the Winston unit for future war combat duty.

As evidenced by the storyboards, the shape-changing and liquid metal properties of the T-1000 would require a wide range of unusual illusions that could be achieved only through computer animation and digital manipulation. And though many of the T-1000 effects would be supported by the artistry of Stan Winston's makeup effects team, the ultimate success or failure of the character clearly depended on ILM's ability to produce computer generated images of unprecedented complexity. Cameron was both excited *and* anxious at the prospect. "I had some idea of what could be accomplished based on my experience with *The Abyss*. But that was an isolated CG scene which I could have cut from the film if I'd had to. For *Terminator 2*, we were looking at using computer graphics to create, in large part, what was fundamentally our bad guy — an ongoing character from reel one to the end of the film. And if there were problems with the imagery, we would have essentially shredded the credibility of the entire film. That was a completely different kind of challenge. So I threw down the gauntlet. I told ILM that this was an opportunity to prove once and for all that photorealistic computer graphics *can* be used in an integrated way to create characters in feature films."

With animation supervisor Steve Williams at the helm, the ILM computer graphics department was divided into six teams supervised respectively by Jay Riddle, Doug Smythe, Lincoln Hu, Scott Anderson, Tom Williams and Stefen Fangmeier, and George Joblove. After studying the storyboards provided by the production, Muren and his team leaders suggested modifications that would accommodate the specific demands of computer graphics. "Some of the boards indicated shots we weren't sure we could do," said Muren. "Some had camera moves, for instance, that would have made our job much more difficult. We suggested compromises; and with Jim's approval, we changed the boards accordingly." As modifications were approved, visual effects art director Doug Chiang redrew storyboards for all forty-three of the computer graphics shots. "We have found that for CG work it is best to be as specific as possible in the storyboarding phase," said Chiang. "After we redrew the boards, we did little animation pencil tests on threes for certain shots. We took the actual layouts and carried motion into them. And that was really effective. It allowed us to get all the timings and action down, and it took a lot of the trial and error out of the animation process."

We'd get Jim's input on the pencil tests; and then, if he wanted us to change something, it was a simple thing to do."

Chiang also worked to define the look of the T-1000 in all four of the computer generated stages that would be revealed as the character transformed through a variety of shapes to his predominant human form. The first stage was an amorphous blob of liquid metal. The second was roughly human-shaped, but featureless. The third was a more distinctly defined metallic man. And the fourth was a virtual replica of actor Robert Patrick who would be playing the character in his human guise. To aid in the conceptualization, Mark Segal of the ILM model shop sculpted several eighteen-inch clay maquettes, detailing each distinct phase. "The maquettes were valuable tools," observed Chiang, "because they were real — something we could study and hold onto. Through them, we were able to figure out how much detail should go into each stage. They gave us a sense of how the character should finally congeal into a man."

Each major transformation required a transition from the 'chrome' man to the live-action character — an organic wipe that would reveal the actor in an interesting and stylized way. Early in preproduction, Chiang — without benefit of reference material — experimented with the effect by compositing a head shot of Patrick with a painted chrome version of the same shot, then hand-animating a transition between the two on the computer paint system. "This was very early on and we were just developing a paint system that would allow us to preview concept art in motion. It was a very important step in developing the look of the wipe, because we could not really refine an effect like that working only with static artwork."

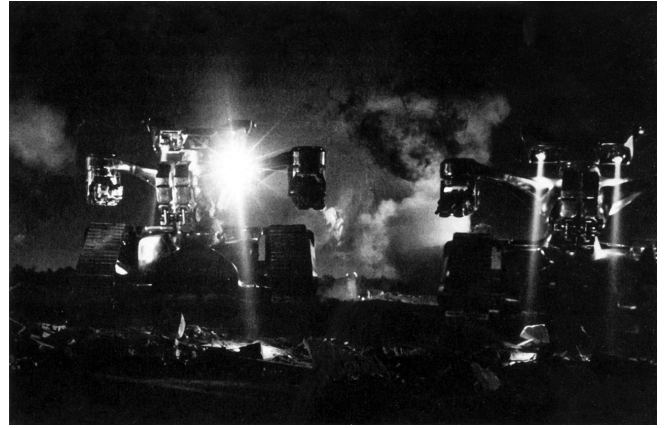
Additional experimentation included computer animation tests conducted against storyboard backgrounds. "We were actually able to begin modeling and animating a rough computer animatic before any photography was done," said assistant visual effects supervisor Mark Dippe. "We digitized the storyboards and used them as temporary backgrounds. Some of the boards had as many as six sequential frames drawn, which gave us a running background. We could create a simple computer model and very rough computer animation, which enabled us to figure out what techniques we might use and what problems we might run into when we did the actual photography."

Before more refined modeling and animation of the character was attempted, the computer team shot extensive reference material of Patrick. "We had *Robert* come up before the show started," said Muren. "He was in nothing but a bathing suit and we put a grid all over him — two-inch squares — then shot him with telephoto lenses from the front and from the side. We shot him walking and running — all the actions he was going to be performing in the film. From that grid, we were able to determine specifically how his muscle structure reacted to each move — which was very helpful when it came time to recreate his movements with the computer model." The dual camera technique had been the brainchild of Mark Dippe. "The cameras were synchronized," Dippe explained, "so that as *Robert* moved, every frame of that movement was shot at the exact same moment from two views. Then we studied that footage for about a month solid. It formed the basis of this whole project — the bodies that we built and the basic walk cycles that we developed out of that reference material were used in over half of the shots we ended up doing."

The laser scanning facilities at Cyberware Laboratory in Monterey — which ILM had utilized in a number of previous shows — proved to be another especially valuable preparatory tool. “We scanned Robert at Cyberware,” said Dippe, “which gave us some digital data to work with. The data wasn’t perfect — we couldn’t use it directly — but it did serve as a guide for modeling the chrome figure. The Cyberware data gave us a basic shape to start with, rather than having to build up the shape from scratch in the computer.”

Four hundred miles to the south, the Stan Winston Studio was likewise gearing up for *Terminator 2* — a project that would prove to be the biggest in the company’s history. Though the facility was already well equipped to handle such a project, the makeup team, like ILM, had its share of research and development to complete before the start of principal photography. Stan Winston had been assigned four major areas of responsibility: creating appliance makeups for Schwarzenegger that would reveal the *Terminator*’s deterioration throughout the course of the film; producing a variety of *Terminator* animatronic puppets for sequences that could not be achieved with either Schwarzenegger or his stunt doubles; devising numerous physical gags and puppets for the T-1000 effects, which would be used in conjunction with ILM’s computer generated imagery; and supplying a number of new, full-sized, articulated endoskeletons for the opening future war sequence.

Designing the look for each stage of the *Terminator*’s deterioration was among Stan Winston’s earliest concerns. Though as many as seven stages were originally discussed, the designs were ultimately simplified to encompass only three: Stage One, which represented the *Terminator* as he appeared before sustaining any damage; Stage Two, which revealed portions of the cyborg’s metal understructure on the forehead and cheeks; and Stage Three, which revealed more of the robotic understructure in the face and limbs, as well as a mechanical eye. To aid in the makeup fabrication — and in the construction of corresponding puppet replicas — numerous facial and full-body lifecasts were taken of Schwarzenegger during early preproduction.



Live-action future war material was enhanced by, and incorporated into, miniature photography produced at Fantasy II. Fabricated in sixth-scale were two formidable HK tanks — one of which was motorized and equipped with xenon searchlights and rotating torso and gun mechanisms.



A war-torn urban wasteland was constructed on stage for the model shoot. Camera operator Christopher Warren adjusts one of the aerial HK miniatures in preparation for a shot. Although motion control was a considered option, all of the flying scenes were eventually achieved with models suspended on wires from overhead tracks or from a crane arm. Cutting the light off at the top of the set effectively rendered the wires in visible.

Though the *Terminator* makeups and associated animatronics constituted a large part of the overall assignment, their design and execution was simplified somewhat by the fact that they were covering old and familiar ground. Much more challenging were the T-1000 puppet and mechanical effects. For budgetary reasons, Cameron had assigned as many of those as possible to Stan Winston's makeup team, keeping the more costly computer graphics shots to a minimum. Ultimately, Winston became responsible for creating dozens of T-1000 effects, including practical bullet hits, full-sized puppets and numerous metallic blade extensions.

Much of the early research and development involved finding ways to convincingly suggest the look of liquid metal in sculpted forms. "We spent weeks shooting pellets into mud," stated Winston, "so that we could study the resulting patterns and duplicate them in our sculptures. We also spent a lot of time testing materials to see which would best take to the vacumetalizing process that would give all the effects their chrome look." Vacumetalizing — which adheres metal particles to surfaces — entails disintegrating a block of aluminum in an airless chamber and electrostatically coating it onto objects and surfaces placed within. "Our main concern was finding materials that would hold the vacumetalizing without cracking or flaking. Ultimately, our best results came from a slip rubber latex that was backed with either a soft foam rubber or polyfoam."

By the time principal photography began in early October, each of the effects teams was prepared to begin work with the main unit. Knowing the amount of lead time required for computer graphics, the producers had wisely scheduled the live-action portions of those scenes early in the shooting schedule. Dennis Muren and key members of his team were on hand to supervise the shooting of their Vistavision plates. "It was very important that we be on the set to shoot the plates ourselves," Muren asserted, "so that we could deal with the many specific choices we would have to make to get the best possible results, and also to respond to any changes Jim might have wanted to make. As it turned out, there were very few changes — the storyboards had been right on the money." To alleviate the complications presented by camera moves, it had been predetermined that the majority of the background plates would be shot locked-off; then, if there was time at the end of the schedule, a slight move could be added. Specific shots requiring camera moves would be photographed with a motion control field recorder so that the moves could later be read into the computer and replicated exactly.

Once a clean background plate had been photographed, Muren and his crew would typically shoot a second plate with Patrick to use as reference when animating their computer model. "We would try to get *Robert* to go through the actions as much as possible so that we could get a performance to copy with our chrome man," explained Muren. "We would ask Jim to direct *Robert* through the performance so we'd have the performance locked — as opposed to shooting a plate and figuring out later what he was supposed to do. Because our schedule was so tight, we had to have as much answered as we could, as early as we could."

Extensive measurements were also taken on the set. "Since we were going to have to put our computer character into that environment," said Dippe, "we essentially had to build the set in our computer. So we measured everything: the tiles on the floor, how far the character was from certain points in the room, the cabinets on the walls — everything. We didn't rely totally on the measurements because there would always be errors, but we used them as a guide to understand

where our computer character should be in space. We also built special targets that were used on the set. Whenever we shot a scene, we'd put that target in front of the camera and roll some film. Then, when we got back to the computer, we'd be able to reconstruct all the parameters. The target gave us a way of verifying that we had the right focal length lens at the right distance from the camera."

Principal photography continued through March 1991, taking the production crew to locations throughout California. Left for last was the future war which serves as a visual backdrop to an opening voice-over in which Sarah recounts the events that lead to Judgment Day. Though in the final film the grim future is established with a minimum number of shots, the director had originally envisioned a future war waged on a much grander scale. "The concept of the future war was enormous," Cameron said, "especially at the very beginning. Then it got scaled back in the rewrites of the script, scaled back more after it was designed, and scaled back even further as the effects shots came in. I was in love with the imagery of the future war; but ultimately, it was not of primary importance because none of the main characters was involved in the sequence. It was only there as a kind of mini-documentary travelogue of the future. It served a specific function — giving the audience a glimpse into that nightmare world — but once it fulfilled that function, we needed to get away from it and get on with the movie."

Using molds taken from the original *Terminator* endoskeleton, the Winston unit constructed four new endoskeletons for the future war — two hero versions, which were capable of gross body movement as well as various head and facial articulations; and two nonarticulated, but posable versions for background use. Though the basic design did not deviate from Cameron's original, the *Terminator 2* endoskeletons were built out of much more lightweight materials. "The original weighed close to one hundred pounds," commented art department cosupervisor John Rosengrant, "and we managed to cut that by about fifty percent for this film. The original was made primarily out of epoxy and steel; this time we went with some hybrid, castable urethane resins reinforced with fiberglass cloth and some metal inside. Also, all the machined parts were made of aluminum this time, rather than steel. There was a trade-off because the lighter endoskeletons were more fragile than the original — but they were also easier to puppeteer."

An early establishing shot employed one of the hero endoskeletons. Revealed in the scene is a grim landscape of children's skulls lying amidst the rubble of a playground. Suddenly, a mechanical foot comes into frame and dispassionately crushes one of the tiny skulls. The camera then tilts up to reveal the cold, frightening face of the endoskeleton as a fireball erupts in the distance. To insure the necessary weight required to crush the skull — which was made of a waxlike material — the heavier steel-and-epoxy leg from the original endoskeleton was attached to the new lightweight puppet which was anchored securely in the ground. The mechanical leg was puppeteered by a rod that attached to the knee. As the camera tilted up from the crushed skull, the puppeteer removed the rod and stepped quickly out of frame. "Control cables for the puppet ran down the support leg," said art department cosupervisor Shane Mahan. "It took one person to operate the leg, and then another four to operate the rest of the body with cable and radio controls. We stood off a good twenty feet to do the puppeteering."



Seven aerial HK models were constructed for the future war and — like the tanks — were vacumetalized to create a glistening chromelike finish. Pyrotechnician Joseph Viskocil rigs one of the dummy versions with black powder and gasoline for a fiery midair explosion.



The stop-motion endoskeleton built for the original film was restored and reconfigured for go-motion use. Rear process plates featuring explosions and aerial HK activity were projected behind a miniature setting on which Peter Kleinow animated the puppet.

Interspersed between the live-action cuts were fifteen miniature shots featuring ground and aerial battle machines constructed and photographed by Fantasy II. Included among the shots were three wide masters designed to set the scene and provide scope to the war footage. The first was an opening scene over which 'Los Angeles — 2029' was superimposed. Designed to harken back to an earlier modern-day shot of city streets clogged with bumper-to-bumper traffic, the camera drifts laterally past rows of charred automobiles — some containing skeletons — to reveal a vista of utter destruction.



To maximize image quality — since the puppet shots themselves were slated for rear process use in scenes with full-size Stan Winston endoskeletons — two rear screens were incorporated into each setup and Vistavision format was employed throughout.

The cars were actual junk vehicles which had been transported to the live-action set — a rubble-strewn demolition site in Fontana — aligned to match the Los Angeles street shot and then set on fire. “The background was constructed in miniature — about twelfth-scale,” said Gene Warren. “There was no action to speak of, other than a little blowing smoke, but the set had several L.A. skyscrapers with maybe six or eight stories left standing — also a collapsed freeway overpass. We had to do a match-move on the model that coincided with the dolly move on the cars. The trickiest part of the shot was the roto work. During the move, almost every frame had to be rotoed very precisely along the roofs and doors of the cars so the background would join in perfectly behind. It was a night shot and the edges were often hard to find.”

Another scope-enhancing composite — which panned past a vista of marching endoskeletons, flying war machines and ground explosions — was realized through a combination of full-size and miniature techniques. The shot — which actually had three distinct levels — began with the photography of four miniature background plates.

To match the expansive future war site in Fontana, the Fantasy II model shop crew — under supervisor Michael Joyce — dressed a roughly sixth-scale setting with miniature cinder blocks, bricks, exposed girders and beams. “We made a series of flexible gang molds,” stated Joyce, “and cast up bricks out of hydrocal and pyrocel. Hydrocal is a particularly hard form of plaster, while pyrocel is a lightweight foaming plaster used for breakaways. There was a lot of rebar in the set, too, plus little metal parts of cars and a freeway overpass. After everything was built and laid out, we spread dirt over the whole thing.” A forced perspective was achieved by scaling down the last few feet of the set by fifty percent. Behind it was a fifty-foot-wide cyclorama with a painted horizon and night sky.

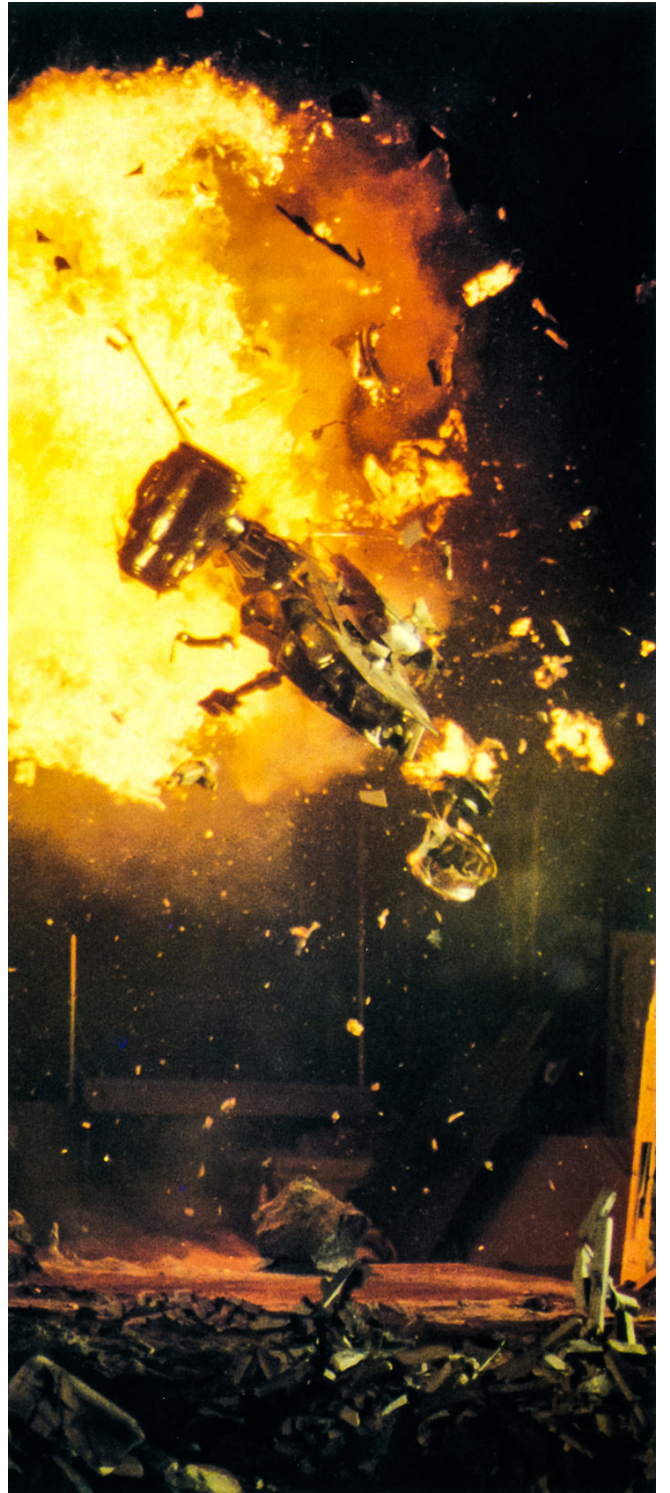
Aerial HKs were mounted on wire rigs and flown over the set. Miniature explosions — rigged by pyrotechnics expert Joseph Viskocil — were detonated and shot high-speed. Because fire and smoke are notoriously difficult to scale convincingly, each explosion had to be precisely rigged. “The idea is to make the small look big,” Viskocil stated. “For that reason, it’s a good idea to stay away from the fast explosives like primer cord. On *Terminator 2*, I stuck basically with black powder bombs combined with magnesium and naphthalene to produce a gaseous fireball but keep it in scale so

that it would match up with the live-action explosions. Our bombs consisted of fifteen or twenty grams of black powder, whereas a full-scale bomb would use up to a pound of black powder.” The miniature explosions — which were shot at around ninety-six frames per second — were enhanced with orange-gelled flashbulbs. “The flashbulbs would go off just before the explosion. So there would be a bright orange flash and then the charge would follow right after that. It helped to stretch out the explosion effect; and for some long-distance shots, we were able to use the flashbulbs alone, without any fire or smoke.”

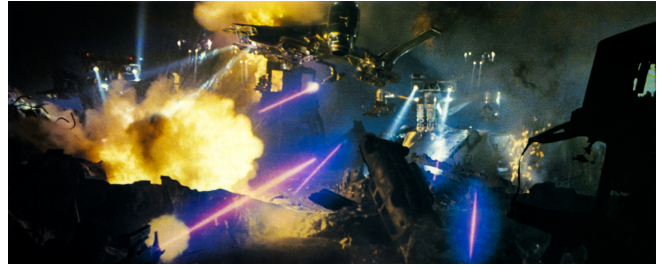
Because the completed master shot would be the product of several rephotographed images — and would be subjected to yet another optical step for rotoscoped laser beams — Warren elected to use Vistavision format throughout and a new finegrain Eastman film stock. “We had done multiple duping tests on 5248,” Warren recalled, “and found that it held up better than all the other stocks around — significantly better. Explosions, in particular, are difficult to dupe because they are so contrasty to begin with. After those tests, I decided to go with 5248 for the background plates.”

Once completed and approved, the four background plates were rear-projected and then rephotographed with a third-scale endoskeleton puppet. The puppet, which stood two feet tall, had been built originally by Doug Beswick Productions for the stop-motion finale in *The Terminator*. Rusted and in disrepair, the endoskeleton was dismantled, thoroughly cleaned and then reassembled. Damaged or missing parts were replaced and the feet were modified to make the puppet suitable for go-motion animation. Warren and puppet animator Peter Kleinow had opted to employ go-motion rather than stop-motion because the miniature endoskeleton shots were slated to be composited into the scene with two full-scale endoskeletons. “My concern was that stop-motion wouldn’t work in these shots,” said Warren, “no matter how well we executed it. Stan’s real ones were going to be right there in the shot with them, and I was afraid that the difference would be too noticeable. The full-scale endoskeletons would be moving naturally and our stop-motion ones would be strobing in the background. So we decided to try for a more natural look with go-motion.”

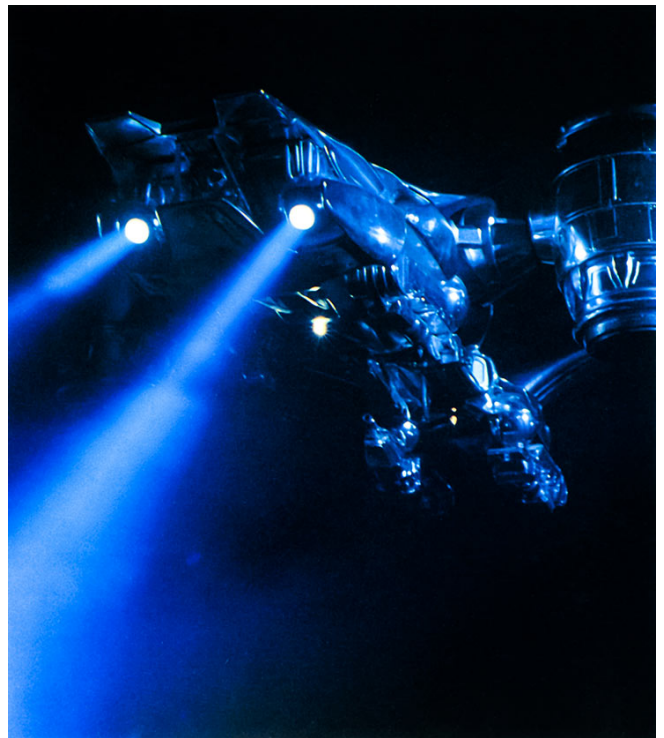
Traditionally, go-motion is achieved with the puppet mounted in front of a bluescreen so that the computer-controlled actuating rods can be optically erased. For *Terminator 2*, however, this additional bluescreen step was eliminated and the puppet was animated within a third-scale setting built to match the scale of the puppet. “The endoskeleton puppet was mounted on a modelmover rod that came up through a slot in the set and attached to the waist in the back,” Kleinow explained. “That’s how we got the gross forward walking movement. The leg that was off the ground was animated via stop-motion — so were the arms and the head. I loosened up the joints of the leg on the ground so it could just follow through with the programmed move. I had to be very meticulous as I animated to make sure that the rod was concealed behind the puppet with each movement. Because the endoskeleton was actually walking on the surface of the set, and because of the natural go-motion blur, the animation had a very realistic look.”



An exploding aerial HK as photographed in the Fantasy II parking lot.

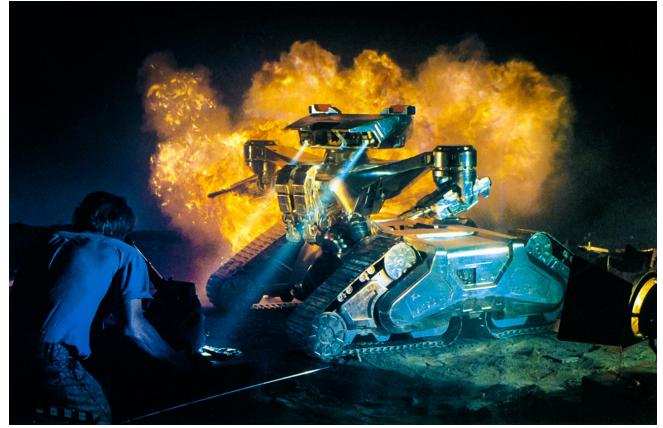


The most elaborate of the future war shots was a split-screen composite incorporating miniature and live-action elements. Photographed first was a foreground plate with human resistance fighters shooting into the distance past a long wall bisected by an overturned vehicle. Beyond the wall — which was made to appear more in ruins by cutting the matte line into it — was an expansive miniature diorama of ground and aerial war machines firing and maneuvering through wreckage and explosions. Rotoscoped laser beams were inserted as a final element.



High-intensity xenon searchlights were incorporated into both the flying models and the tanks.

To insure a high-resolution image, each of the puppet setups employed two rear process screens positioned side by side with miniature set pieces obscuring the inner screen edges which would otherwise have shown on camera. The same approach would later be used on the live-action process stage where the go-motion puppets would be combined onto a single piece of film with their full-size counterparts. After animating the puppet against one pair of background plates to produce the left side of the plate for the finished shot, Kleinow repeated the process against a different pair of plates for the right side of the shot. Interactive lighting — cued from explosions and searchlight activity in the plates — was added to the puppet and the third-scale set via motion control. Camera operators Spencer Levy and Michael Karp oversaw the lighting and computer programming. The end result was two Vistavision plates — each with a single endoskeleton walking against miniature background footage. The final foreground imagery — a pair of the full-scale animatronic endoskeletons — was then photographed on the production process stage with a similar dual screen approach. Featured in the final layered shot were ground explosions, an aerial HK and four walking endoskeletons.



As an explosion blossoms behind it, visual effects supervisor Gene Warren photographs one of two HK tanks constructed for the project.

Though the endoskeleton shot was among the most difficult of *Fantasy II*'s future war assignments — taking more than three months to complete — subsequent scenes of the ground and aerial war machines in various maneuvers presented their own challenges. Unlike the endoskeleton puppet — which was left over from the first film — the HK tanks and aircraft had to be built from scratch, largely to accommodate a change from roughly one-twelfth scale to one-sixth scale. While the exterminating machines in the modestly budgeted original film had sported little detail and had been finished with only a silver paint job, the models for the sequel were upgraded with fine detailing and vacumetalized to insure a gleaming metallic surface.

Seven aerial HK models were built — two fully-functional hero models and five dummy versions for use when the aircraft crashed or were blown up. "The parts were carved out of a dense foam," said Mike Joyce, "and then surfaced with polylux to make them smooth. We made up rubber molds from those pieces and then laid them up in epoxy and fiberglass and put them together. The flying HK had no movement in it except for its xenon lights — it did have a rotating beacon and running lights on the tail section which were radio-controlled." Dummy versions of the aircraft were equipped with the running taillights, but not the xenon searchlights. "For one shot of the aerial HK blowing up," Warren noted, "we put in the searchlights optically for twelve frames or so before it explodes. The lights were shot motion control against black, then matched up to the model."

Warren had anticipated needing motion control for one or two of the more difficult flying maneuvers. Ultimately, however, all of the flying shots were achieved with wire rigs. “We flew them two different ways. For some of the shots, the model was hung on a sixteen-foot crane arm capable of producing curves and dips and altitude changes. Then, for shots where the flying HK just went through the background, the model was suspended from wires attached to a cable and tracks. The crane was also used for closeup flying shots where we were tracking the HK. In those situations, the model was just hanging in place with smoke blowing by and the scenes were shot undercranked at about sixteen frames per second with a hand-held Vistavision camera. My son Chris was like a moving tripod — we put a camera on his back and he bent over and walked around, tracking the model.”

The night setting made optical wire removal, for the most part, unnecessary. “All we had to do was cut the light off at the top where the wires were. There were a couple of shots where an explosion went off behind the flying HK and made some of the wires visible, so we had to get rid of them on those shots. We did that with garbage mattes — pulling high-con mattes right off the wires themselves and then isolating and printing back in the explosion.”

Joe Viskocil was called upon to rig the midair explosion. “We went through all seven of our models to get it right — mainly because there were conceptual changes in the shot. Originally it was boarded simply to blow up in midair, but then Jim decided he wanted it to hit the ground first and then blow up — which was a real trick because it was all in one take.” The HK was filled with model pieces to create aesthetically pleasing debris as it exploded. “We placed six individual charges throughout the model, using gas and black powder. Everything was electrically detonated and we had a timing box so that we knew exactly when each charge would go off. The model was hung on a rig and we set up trips so that as it hit a particular spot, the trips would release the ship and it would come crashing down. Then we would set off the individual explosions. It was difficult because we were shooting at forty-eight frames per second; and at that frame rate, we had to get the model moving at about twenty-five miles an hour for it to look right.”



Several specialized Terminator puppets were required for the film. For scenes in which the cyborg was to be shot in the face — revealing his chrome endoskull beneath the torn flesh — an articulated replica of Arnold Schwarzenegger was fashioned by the Stan Winston unit. Mounted on a custom walking rig, it was operated by art department coordinator Shane Mahan, with remote puppeteering assistance from three additional crew members wielding cable controllers.



Also constructed was a mechanical arm and hand that was used on one of the endoskeletons during the future battle and then fitted later onto Schwarzenegger for a scene in which the Terminator peels the flesh off his arm to evince his nonhuman nature.

Massive HK tanks were also featured in the sequence. Sculpted out of the same dense foam as their aerial counterparts, the tanks were made from epoxy, gel-coat and fiberglass. “The tanks were much more sophisticated than the ones in *The Terminator*,” noted Joyce. “They had torso rotation, gun rotation and movement of the head and searchlights. In the first movie, we got by with quartz lights for the searchlights; in this movie, we used xenon — smaller versions of the type used in police helicopters. There was also a lot more detail in these tanks — all the little cubbyholes and the claws and the guns were detailed. Also, it had four motors instead of just two — one in each tread — which made it turn better. The tank ran on its own, with a tether that went out the back to carry the power. Each motor had its own controller and each xenon light had its own power supply. The head and torso and gun rotations were all radio-controlled. The finished model stood four feet tall and weighed about two hundred fifty pounds.”

“We also built a second tank,” Warren noted. “It didn’t have motors on its treads, so we had to pull it to make it move. In fact, nothing on it was motorized except the running lights. Everything was operated by human power off-camera with monofilaments and lines. We used that model in two shots where it was in the background and the hero tank was in the foreground. One of them was our big ‘War of the Worlds’ shot that had two HK tanks, a few flying HKs and a bunch of explosions all split-screened into a live-action plate of soldiers running and shooting in the foreground.” Among the other Fantasy II shots were various tighter views on the war machines — including aerial HKs in flight, tank treads crushing human skulls and closeups of blazing gun turrets.

All of the miniatures shots — plus most of the accompanying live-action — required laser blasts that were created via cel animation, then optically composited. “It was standard rotoscope work,” said roto supervisor Bret Mixon. “We had to add lasers and muzzle flashes and interactive lighting every time a gun went off. There were forty-six shots in the future war sequence and almost all of them had laser fire. The lasers were all bottomlit animation; the muzzle flashes and the interactive light were toplit artwork. We wanted to match the look of the lasers to the first film, so we took out our notes on what had been done then. Our lasers are the same color — a white core with a magenta glow that falls off to blue — but in this film, they look more like tracers than actual laser beams. In the wide panoramic shots, they recede in the distance and disappear into little dots.” Although the live-action future war was originally slated to be shot midway through principal photography, a scheduling change shifted it to the very end of the six-month shoot. As a consequence of the late delivery of plate material, Fantasy II had to hire an army of roto artists and put them on around-the-clock shifts laying in laser beams. “What made the work a little more difficult than normal,” noted Warren, “was that all of these shots were moving and hand-held and jumping around — they were all over the place. Also, the laser beams had to pass behind things in some shots, so those frames all had to be rotoed and holdout mattes had to be made.”

After the prologue, the action shifts from the grim future to the present, where we witness the arrival of the *Terminator*. Though in the original film the arrivals of both the *Terminator* and Kyle Reese had been cheated somewhat with cutaways, the *Terminator*’s entrance in the sequel was to be displayed from beginning to end. Practical lighting effects such as flashes and sparks had been shot live-action to support the rotoed effects planned by Fantasy II for the arrival sequences. “We rotoed down the background of each shot,” said Bret Mixon, “so we could plot where the lighting effects were in the frame and match our electricity shots to those. Then we shot Tesla coil electricity

on the stage against black, using those roto drawings to site through the camera so that the electricity would arc to a specific point.”

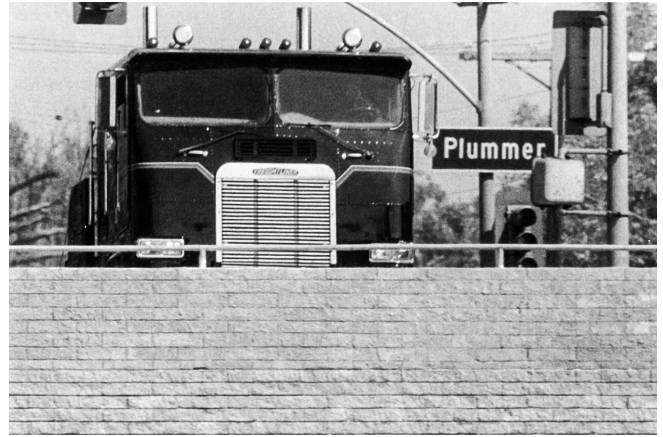
In addition to lightning, the arrival effect featured a ‘time bubble’ in which the *Terminator* was transported. “It is a kind of sphere with energy inside and lightning coming off of it,” explained Warren. “To create the bubble, we shot straight down into a ten-inch-long plexiglass tube. At the top of the tube was a pan of dry ice. We lit it all the way down. At the bottom, there were hot lights shooting up, and the dry ice poured out around the light. We shot it at something like six frames per second and the effect was very unusual. The black sphere itself was rotoed animation. It comes out from infinity in only twenty frames, so it is fairly quick. Then there is a white-out and Arnold appears. That particular shot took about nine hours to comp and required something like thirty-two passes on the printer.” Adding to the complexity of the effect was the fact that newspapers and trash were blowing through the live-action, necessitating numerous holdout mattes.

As in the first film, the *Terminator* has arrived nude. Unable to pass without notice in such a state, his first order of business is to procure suitable clothing. Entering a crowded biker bar, he scans the room in search of an appropriately sized donor. The sequence featured the first of many ‘Termovision’ effects used to depict the cyborg’s computer-display-like point of view. Visual effects coordinator Van Ling was responsible for designing the video graphics imagery which was subsequently produced by Video Image under project supervisor Richard Hollander. Though the script had specified eight scenes in which the Termovision effect would be displayed, several additional ones were ultimately included. “We used the Termovision shots to help tell the story,” Ling commented, “and to reveal the *Terminator*’s reaction to certain events. Since he is not given to emotional outbursts, the Termovision was a way to let the audience see what was in the mind of the machine.”

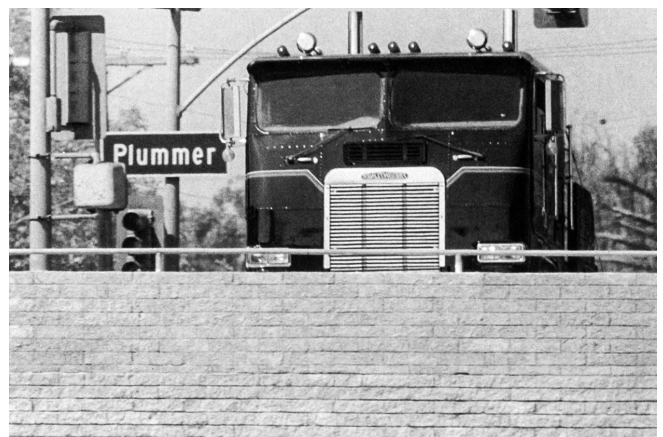
Ling created very detailed storyboards for the Termovision shots, each of which was composed of two elements — a plate that revealed what the *Terminator* was viewing, and then informational graphics which were laid over that imagery. The process began when approved background plates were turned over to Ling who transferred the material to video. “I scanned a few frames from the videotape into my computer — just enough to create a storyboard,” said Ling. “Using the Photoshop program, I then colorized those specific frames to the characteristic red of the Termovision shots.” The next step was designing the graphics overlays. “I had to compose the graphics so that they wouldn’t obscure the background imagery too much. Each shot had a big graphic text window and then smaller ancillary graphics to show that there were other things going on. I tried to match the look of the Termovision in the first film since this was the same model *Terminator*. I watched the first film, drew those graphics into the computer and then used that as my model.” Though the Termovision shots in *Terminator 2* were similar to those in the first film, Ling elaborated on the basic concept. “In this film we reveal a greater range of program capabilities that the *Terminator* has. He is able to scan people and shapes, enhance images, do playback and in-depth analysis.” After the placement and content of the graphics was determined, the material was put together with the red background imagery and then outputted for Cameron’s approbation.

Once approved, the storyboards were turned over to Video Image — which had already been contracted to provide on-set video assist for the production — where the final shots were produced digitally. Though the Termovision shots in the first film had been optically achieved, the advancements in digital technology in the seven years between the original and the sequel made digitally produced effects the more efficient choice. “I was given an interpositive of the shot,” said Richard Hollander, “and editorial counts with a sixteen-frame handle on either side of the cut. I took that interpositive and scanned it in on our high-resolution scanner, bringing that into my computer system. I also had Van Ling’s storyboards and verbal descriptions to guide me in what the graphics should look like. We wedged out the coloration of the background and picked whatever color would work for the scene. The film we got ranged from high contrast to very low contrast, which made it a real technical challenge. Every Termovision shot was different in terms of having to emphasize or deemphasize the background.”

Termovision’s monochromatic red imagery served to simplify the preliminary stages of the process. “Our scanner is a charge-coupled device that uses filtration to separate out red and green and blue and store those individual color values in digital form. However, since we needed only a monochromatic image to work with, it was not necessary to do a full color scan. By shining the color image of the IP into the CCD array without any filtration at all, the system looked at the entire color spectrum and responded to the luminance or brightness of the image rather than the coloration. The result was kind of an average of the colors — not evenly weighted, but sufficiently accurate to represent the imagery that we needed to see. Even with the partial scan, the amount of data was enormous — more than a million bytes per image — but a technique called run-length encoding allowed us to compress that data and make storage easier.”



Early in the film, a tow truck commandeered by the T-1000 — an advanced terminator sent to assassinate young John Connor — is driven headlong through a wall and into a fifteen-foot-deep drainage canal. The elaborate stunt was shot live with spectacular results. In editorial, however, James Cameron determined that the scene would cut better if the truck were approaching from the opposite direction. This could have been accomplished simply enough by optically flopping the shot — except for a large street sign positioned prominently in the frame. Pacific Data Images took the original shot and scanned it into their computer system, then digitally flopped the essential image while retaining the sign in its proper orientation — with some additional high-tech tweaking to correct the perspective shift and conceal the dummy driver who was now on the passenger side of the truck cab. Then it was scanned back out onto film and cut into the picture.



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Each of the one million pixels per image was represented by a numerical gray scale value ranging from zero for pure black to 255 for white. By manipulating the data, the white portion of the scale could be altered so that the blacks would be retained, but the lighter values would become equivalent shades of red. The formula was altered slightly by the determination that the brightest highlights in each shot would be pure white, and then the darker gradated tones would range through the red scale to pure black.

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When the color wedge for each shot was approved by Cameron, Hollander and his crew proceeded to program in the graphics material. “Each overlay was dictated by the scene. The text and numbers required a font that we did not have on line, so we generated our own by digitizing a frame of each letter and transforming it into polygon form. We had to do that only once for each letter. The characters were then orchestrated to wipe on and animate, and we used generalized programs to make the data look like it was being printed by a computer. After it was put together, we would produce a test at video resolution which we would then convert down to simulate twenty-four frame viewing. We put each of those frames onto a videodisk, which plays back at thirty frames per second. Then we took that and slowed it down to eighty percent using the standard conversion machines. Once the graphics were approved, we married the overlay and the scanned-in live-action on the computer doing what was effectively an optical composite. In some cases, the image also had to be distorted with static or distortion effects. Individual frames were saved as files and then delivered to our Solitaire printer which put them out onto film.”

The first Termovision shot specified in the script was a POV of the *Terminator* as he walked into the biker bar. “For that sequence,” said Ling, “we roto-framed the patrons or the vehicles he passed to indicate that he was scanning them. It was a white outline that popped on the image — two or three frames’ worth — just long enough to show that he was checking them out, like a glance.” A later Termovision shot in which the *Terminator* targets John Connor featured a zoom window. “For the shot in which John is identified in the canal, we not only shot a background plate, we also shot a still at the same time. That way, we could zoom up to the still in the graphics window and get a higher resolution image than we would with just a freeze-frame from the film. Video Image zoomed into the still and airbrushed it on the computer to get rid of anything we didn’t want to see. Then we took that image — which was very crisp — and did a digital mosaic. In other words, we averaged every group of four pixels to one pixel color, which lowered the resolution of the image. We did that successively and then ran it in reverse to suggest that the *Terminator* could take a low-res image and make it crisper as he zoomed in on it.”

Oblivious to the fact that not one, but two terminators are looking for him, young John Connor — played by Edward Furlong — evades the demands of his foster parents by hopping onto his Honda dirtbike and heading to the video arcade at a large shopping mall. Both the *Terminator* and the T-1000 track him there. In their first exchange of gunfire, the liquid metal composition of the T-1000 is revealed when a swarm of bullet hits produces only temporary splashes in his perfect cop disguise. The effect was one of the earliest tackled by the Stan Winston team. Dozens of latex and foam pieces — which simulated the look of a rippling hole in liquid metal — were sculpted in a

variety of patterns and sizes, then vacuum-metalized. Meanwhile, crew members under mechanical coordinator Richard Landon labored to devise a mechanism that would reliably open the splash wounds — which looked rather like chrome flowers. “The first thing we made was very simple,” said Winston. “It was a little flap that opened like a bear trap mechanism. I showed that to Jim, and he said, ‘Well, I’d really like something more ... elegant.’ So I thought, ‘Okay, we’ll design something ‘elegant.’”

The mechanics team eventually engineered a mechanism conceived by Chris Cowan. “The hole where the chromed flower was to come through the clothing was divided up into five pieces — almost like a pie,” said Landon. “Each one of those pieces was tacked down with medical adhesive to a spring-loaded finger mechanism that upon actuation would jump outward from the center. They were like five little trap doors. The foam rubber flower was glued to the underside of those fingers and the whole thing was carefully folded shut.” The flowering device was attached to a fiberglass chest plate worn by Robert Patrick under his prescored cop uniform. “The mechanism was actuated by a single radio-controlled cable pin release. When we threw the switch on the transmitter for the servo control, it would pull the pin out, releasing all five fingers at once. The impact area of the shirt would suddenly vanish and be replaced by the chromed flower. We used very beefy springs — they were so strong that it just about killed the servo to close them — but the strength of the springs opened these things instantaneously.”

Because of the hair-trigger quality of the mechanisms, the bullet hits were frustratingly difficult to deal with on the set — particularly during the rough-and-tumble action scenes. “I think we over ‘elegantized’ ourselves with those damned flowers,” lamented Winston. “We had backup shirts; and the plan was that while one was being shot, another could be reset so there would be no down time. But I don’t think there was ever a day when we used these things that we didn’t end up waiting on the reset. We were constantly fighting to get through a shot where the mechanisms would stay closed until we were ready for them to open — and then *would* open when they were supposed to.”

The closing of the bullet wounds was a computer-generated effect. Because of the high cost of the technique — and the large number of bullet hits that would be needed throughout the film — Cameron had decided upon a cost-effective alternative to having wounds constantly appearing and healing. “We made the decision along the way to not have the impact effects of the bullets heal immediately,” Cameron stated. “Instead, we decided to let the T-1000 accumulate a number of injuries and then heal them all at once. That was one way in which we were able to lower the number of CG shots in the show. So, for example, in the initial confrontation between the two terminators, you see the T-1000 get shot six times, but you see him heal only once — one computer-graphics shot as opposed to six.”

To digitally heal the bullet wounds, the live-action plate was first converted to an interpositive which was then scanned into the computer. “We use a charge-coupled device scanner,” said Dennis Muren, “rather than the laser light we used a few years ago. The CCD has tiny buckets that pick up a certain number of electrons, depending on the amount of light that is available. The scanner can read four thousand pixels across. As the film runs past it, it reads a row and digitizes it.” After the film plate was scanned at high-resolution, a low-resolution working version was generated in the computer. “We do our initial modeling and animation on the low-res version,” said Mark Dippe, “using the Alias system for our basic animation. We match-modeled Robert Patrick’s live-action

torso — which sported several of Stan Winston’s chromed bullet hits — in the computer. Next we put a computer model where his torso was, using Stan’s bullet hits as guides to make 3-D computer models. Then Jonathan French animated those computer modeled hits to close up.”

The effect was enhanced with a rippling program — one of many custom software programs designed for the show — which made the clothing around the wounds distort and move as the healing progressed. “Rather than a three-dimensional modeling technique,” explained Doug Smythe, “rippling is two-dimensional image processing that shifts pixels around in the frame, allowing us to move and distort all of those points without having to move them by hand.”

Typically, a variety of software programs was applied to render the computer graphics model. “We use Renderman software to do all of the texture mapping onto our model,” said Dippe. “One of the key things for *Terminator 2* was figuring out how to get the right look for the shiny metal material. We came up with a very sophisticated shading program that we called the polyalloy shader which gave us all the properties we wanted for the T-1000 — kind of shiny, reflective, slightly cold and silvery.” After rendering, the computer generated imagery was digitally composited with the high-resolution background and the completed shot was scanned back out onto film.

Among the advances realized for *Terminator 2* was the intercutting of digitally composited material with live-action footage. “In *T2*,” commented Muren, “there would be five minutes of real film which then had to intercut with a bright daylight shot that was composited digitally. We were all very interested and concerned about how well that was going to work. Fortunately, we found that digital compositing works very well — and it is a tremendous benefit for everyone. There are no matte lines, and grain differences are not a problem because everything is scanned in from the same film stock. There are a lot of advantages to digital compositing.”

As the two adversaries from the future square off at the galleria, John manages to escape on his dirtbike, racing into the maze of flood control channels criss-crossing Los Angeles. Both the *Terminator* and the T-1000 follow — the former on motorcycle, the latter in a tow truck. The chase



Digital image processing was also used to depict the Terminator’s point of view. Moments after his unclothed arrival from the future, the cyborg unabashedly enters an inhospitable biker bar and surveys its clientele looking for someone whose clothing might fit him. Live-action plate material was scanned into a computer at Video Image and color-adjusted to the characteristic red tones established in the original film. Appropriate text and graphics material was then generated and incorporated into the shots.



Preparing to engage a heavily armed SWAT team, the Terminator performs a summary threat assessment. Used sparingly in the film, the ‘Termovision’ shots were designed specifically to provide story points and afford a glimpse into the thought processes of the taciturn cyborg.

sequence through the narrow concrete canals featured two remarkable stunts — a tow truck crash through an overpass wall into the canal and a fifteen-foot motorcycle leap onto the canal floor. Deemed too dangerous to attempt free-style, the bike stunt was achieved by mounting the motorcycle and rider on a cable rig and lowering them into the channel. Similarly, the tow truck — which carried only a dummy driver — was cabled on both sides, pulled up to speed and then released slingshot-style to crash through a soft plaster wall and into the canal.

Both scenes would be altered digitally by Pacific Data Images — a facility specializing in computer graphics and image processing. The motorcycle leap required the removal of both the support wires and the overhead rig. The first step was to scan the original film footage into the computer. “After a shot was scanned in,” explained facility effects supervisor Jamie Dixon, “we could display a frame at a time on our computer screen. The next step was to identify where the wires were. We have a program that is comparable to hand-rotoing. We can go in every three or four frames and, using a mouse, define the end points of the wire in that particular frame. So we manually determine the points — but we don’t have to do every frame that way. The software allows us just to do key frames. Then it fills in the rest. Once we had those end points specified, we used another software program which basically takes whatever imagery is on either side of the wire and interpolates across the wire to fill in the area with that imagery. The program runs automatically. Sometimes the interpolation would be off a bit because there was a jerk in the camera move or something. When that happened, we would have to go in and pin it down by hand.”

Two shots required wire removal. The first was a medium shot of the motorcycle in midair against a blue sky; the second was a wider view as it soared past some trees and landed on the canal floor. The simplicity of the sky background made for uncomplicated wire removal in the first shot. The second shot, however, was more of a challenge. “The wires in the second shot were against moving trees; so we had to be much more accurate with our wire placement, making sure that we only went into the parts of the frame that needed fixing.” Adding to the complexity of the wire removal was the camera move. “If this had been a locked-off shot, it would have been very easy to get rid of the wires because we could have just taken a shot of the trees where there were no wires and filled in that detail from a previous frame. But the camera was moving constantly, following the action, and we found that on a moving shot the eye is very good at picking up disturbances — anything that isn’t quite right in the frame. There were also a lot of little problems on that shot. When the motorcycle hit, for instance, the rider jerked forward a bit and the wire went in front of his face. So for those few frames, we had to go in by hand and digitally paint out the wires. Also, the sky was much different in color than it was in the preceding shot — so we had to blue it up to match. And Jim Cameron wanted us to add a slight tilt-down to emphasize the height of the jump. So there was a lot of trial and error involved.”

A significant difference between the digital and the optical realms is that, for digital purposes, the more obvious a wire is in a shot, the easier it is to remove. “If the wires were painted orange or some other color that wasn’t in the rest of the shot,” said digital/optical supervisor Les Dittert, “it would be very simple for the computer to detect that wire automatically. We wouldn’t have to identify the wire manually at all. But it is very difficult to get a director of photography — who is accustomed to thinking in terms of concealing — to agree to use orange wires in a shot. Hopefully, as filmmakers become more acquainted with this technology, that kind of thing will become

commonplace.” The fix-it crew at PDI had no trouble locating the motorcycle support rig — which was clearly visible and prominent in the frame. “A lot of directors would have tried to hide the rig,” observed effects producer Julia Gibson, “but Jim was very enthusiastic about the possibilities of digital manipulation; and so he just said, ‘What the heck,’ and didn’t worry about hiding the rig at all. As a result, there was a very large area to be filled in — about an eighth of the frame — because the rig was a fairly large device.”

The plummeting tow truck also required digital processing — but for a different reason. Though the action had been photographed from a particular vantage point, as the sequence was edited, Cameron determined that the narrative flow would be better served if the truck were to crash through the overpass wall from the opposite direction. Optically flopped shots are a common enough solution to problems of orientation and screen direction; however, in this instance, that approach was essentially obviated by a large street sign that was right in the middle of the frame. The only solution seemed to be to digitally flop the shot without flopping the sign.

Even as they presented PDI with the challenge, the filmmakers were skeptical that it could be met. “Their attitude was, ‘Well, give it your best shot,’” Dixon recalled. “But it turned out to be very easy. We scanned in the frames, then extracted the area of the frame that the street sign was in so that we could deal with as little data as possible. One of the nice things about working in digital is that we can cut out — as if with an X-acto knife — a certain area of a frame and then put it back in completely intact. The biggest problem with the shot was that it was hand-held and everything was wiggling around as the camera followed the truck breaking through the wall. So we used software that can watch details from frame to frame and then spit out how much that detail has moved in subsequent frames. We fed those numbers into a little compositing script, then offset the unflipped sign by exactly those numbers. That way, we effectively composited the correct sign back over the top of the flopped sign.” Perspective adjustments were required to perfect the shot. “When we first put the sign in there, it looked totally wrong. So we used our morf tool to bend the sign into the right perspective. It was a fairly simple distortion, but it was necessary in order to put the sign into the frame correctly.” Also required was a digital version of a hand-drawn rotomatte. “There were a few frames where the truck crossed over the sign. We went in by hand using a paint-through technique where we put the correct frame in the background and the one we want fixed in the foreground. Then we reveal the corrected information for whatever few frames are required. In this case, we were revealing the truck. It’s kind of like a wipe. We have the correct picture behind and we digitally scrape away the top picture to reveal that correct image.”

Since the wires and the support rig were unavoidably visible in the photography, Pacific Data Images was engaged to remove them digitally — a process which entailed isolating the unwanted elements within the frame and replacing them with imagery interpolated from either side. Digital supervisor Les Dittert studies one of the unaltered shots on his monitor.

Although most of the canal chase was filmed live on location, a few key shots were accomplished via rear projection on a process stage. Included was one in which the Terminator plucks John from his bike just as the tow truck is about to run him down.

The only other clue that the shot had been flopped was the dummy driver in the truck cab who was now on the passenger side. Rather than flopping the barely visible image, PDI opted instead to darken the window so that the figure was completely obliterated. “There were a lot of reflections and rocks and dirt that were blowing up in front of it in the frame, so we decided that the simplest thing to do would be to get rid of the image completely. We ended up cloning another part of the window that had comparable detail in it, and basically pasted that over the part of the window where the driver was. Luckily, the window was flat so there was a large area of similar detail that we could draw from. It’s a common digital painting technique — using an image from one part of a frame to paint over another part of the frame.”

The canal chase ends abruptly as the T-1000 crashes the tow truck into a concrete abutment. As the wreckage explodes, the liquid metal terminator strides purposefully out of the flames in his chrome man form and shifts back into his human cop disguise. Shooting the plates for the scene — which would feature a clean transition from the computer generated character to the live-action actor — was particularly complicated. Originally slated as a motion control shot — with one pass of Robert Patrick walking from the area of the fire, and a second pass, without Patrick, into which the computer imagery would be inserted — the shoot



Determined to rescue John Connor — whose dirtbike is losing ground to the barreling tow truck — the Terminator jumps his motorcycle into the flood control channel. The stunt was accomplished with an overhead wire rig that supported both the motorcycle and its rider as they shot outward and into the canal.



did not go as planned. “It turned out that we could never get Robert’s moves synced to the prerecorded camera move,” stated Cameron. “We tried doing it by counts and everything, but we just couldn’t get it to work. So eventually we had to go with manual moves. We put out the fire and we put Robert at the start mark, back where the fire was going to be. Then we had him go through the action — we probably did it twenty times — and the camera operator memorized the camera moves on him. We counted it out — 1001, 1002, 1003 — and by those counts, the cameraman would remember to pan a little or tilt, or whatever the move for that count was. It was like human motion control.”

Once the camera operator had memorized his choreography, the fire was reignited and the plates were photographed. “On my count, Robert would get to a certain point which was marked off on the ground and then start walking forward. Meanwhile the cameraman would just slowly and subtly adjust his position so that Robert was in frame. Those camera moves were recorded by the field recorder. Then, while the fire was still burning, the motion control system was set back to the home position, we rolled again and set off the move we had just recorded seconds before. That way, we got a plate that was empty of Robert but had the same fire burning and the same lighting conditions and the same camera moves.”

Shot early in the production schedule, the scene was a true ‘trial by fire’ for Robert Patrick. “Jim had told me to run into the fire as far as I could without getting burned,” Patrick recalled. “But I’m a gung-ho dude, and I ran in so far that there was fire all around me and I knew I was in trouble. I felt this intense heat and I could smell my shirt beginning to singe — and the back of my ears were stinging. I heard ‘Action’ and I walked out calmly — but then I could feel myself starting to fry and I began walking faster and faster. When it was over, Jim came up to me and said: ‘Robert, I appreciate your dedication, but I think you overdid it. Don’t run in so far next time.’ We wound up doing it over and over again, and I had to try to repeat my stride exactly on each take. It was really tough. It was the first time I realized how hard doing this stuff with the computers was going to be. I really had to concentrate on what I was doing.”

The plate was shot with synchronized dual cameras, which provided vital reference material for computer animator Steve Williams. “At the same time we were shooting the ‘A’ camera, which was the actual scene, we were also shooting a ‘B’ camera, which was the side view of everything Robert was doing. Both were synced together frame-wise, so I had side reference to help me figure out how long each of the character’s steps should be.” As storyboarded, the T-1000 that first emerges from the flames was to be the very smooth, featureless version — the Number Two chrome man — which would then transform through the intermediate Number Three into the detailed chrome Number Four and finally into the live-action Robert Patrick character. Williams was responsible for building all four stages that were used throughout the film — a painstaking process that took several weeks to complete. After constructing the basic models in wire-frame form, Williams began the animation process. “Essentially, the model is a digital puppet. You bend the arm up, and then from the arm you bend the forearm, and from the forearm you bend the hand — setting a key frame for all three of those moves. Then, when you play it back, it actually goes through those motions. And every time it does that, it generates a parameter curve which gives you a visual graph interpretation of the move from the frame range.” Animating the chrome man walking out of the fire was among the most difficult computer graphics tasks in the show. “People have been trying to do that kind of thing in

CG for twenty years. Jim Cameron had told us that those shots represented a lot of his thoughts about the invincibility of the character — so we had to get them. I just did it and redid it and redid it — probably three hundred times a day. Each time I would make very slight mannerism changes — swiveling the hips just a bit, flipping a wrist a little more, adding a slight head movement.”

Once the animation was completed, the wire-frame form was rendered with custom software. “We were creating a human body,” noted Mark Dippe, “which is a continuous thing. So we came up with software that we called ‘Body Sock’ which allowed us to connect the distinct and separate pieces of the body which Steve had modeled, smoothing out the joints between those pieces. Body Sock moved specific points while maintaining continuity so that we wound up with a smooth skin.” The polyalloy shader was also utilized to give the completed figure its chromelike appearance. It was also during the rendering process that elements were added to marry the computer generated figure to the live-action. “One of the most important things was to make our computer character look like it was actually a part of the photography. So we were very careful to match the lighting of the live-action — where the lights were and what kinds of lights and gels were used — in our computer. We matched the colors and the intensities and the positions — everything. Alex Seiden wrote the program for that.”



As the metallic figure proceeds toward camera, he metamorphoses — in one unbroken shot — from his featureless humanoid form to a detailed human form to the live-action form of actor Robert Patrick.



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Because the T-1000 in his polyalloy form was a highly reflective entity, it was necessary also to incorporate reflections onto his surface. “When we were on the set, we took still photographs of all the surrounding scenery. We’d stand where the character was going to be and shoot a panorama of everything all around. Then, when we came back, we scanned those still photographs with a Nikon 3500 slide scanner into a Macintosh FX computer running Adobe Photoshop. We could surround our chrome creature with those photographs and reflect all of those pictures off of him. The reflections really made him look as if he was in the environment.” Similarly, the team would often cast reflections *from* the chrome character. “A very bright object like the T-1000 would, in reality, scatter bright reflections on the ground. So we put reflections in the water in the shot of him walking out of the fire.” Other environmental tie-ins — shadows, smoke, heat distortions and even film grain — were also added. “Those are the kinds of things that are often overlooked in computer graphics — those elements that marry the computer element with the photography. Without them, the computer element would look like a cookie-cutter shape pasted on top of the live-action.”

Although painstaking measurements of the canal set had been taken, the final animated character did not line up perfectly with the live-action photography. “The character walked perfectly on our computer floor,” said Dippe, “but it did not move perfectly on the real floor in the photography. One of the reasons was that the camera was moving in the shot; and even though we had a motion control system, there was still some error when we duplicated that move in the computer. Also, the canal floor wasn’t perfectly even — every measurement we took of it varied by a few degrees. So we just had to do the best we could, touching it up with hand painting and using our morphing technique to adjust it.” Morphing — which had been developed by ILM for *Willow* — is an image processing technique which alters two-dimensional imagery. “Morphing transforms one image to another,” Doug Smythe explained, “by stretching each sequence of images to match into an identical intermediate shape and then cross-dissolving between the two distorted images. To make the effect more interesting, we vary the rates at which the different parts stretch and dissolve.”

The transition from the Number Two chrome man to the Number Four was done using ‘Model Interp’ — another piece of software designed specifically for *Terminator 2*. “Model Interp takes two arbitrary shapes and allows us to evolve from one shape to the other,” explained Dippe. “It’s like a 3-D version of the morphing technique.” The final transition from the Number Four character to the



The computer graphics department at Industrial Light and Magic produced more than forty complex shots for the film — including numerous transformations. The T-1000 character was defined and created in four distinct shapes ranging from an amorphous liquid metal blob to a precisely replicated human surfaced in shining chrome. Shot supervisor Lincoln Hu — one of seven on the project — checks the color balance between the plate and the digital composite.

live-action Robert Patrick was accomplished by lining up the computer image to the live-action and then doing a wipe between the two. “The wipe moved in 3-D across his body. The edge of it was essentially a split line between our chrome character and the live-action which had been lined up perfectly.”

The tow truck crash and subsequent explosion afford John and the *Terminator* just enough time to escape the T-1000. Once on the road, John insists on stopping to make a warning telephone call to his guardians. His call comes too late, however. As he speaks to his suspiciously pleasant foster mother on the phone, Janelle Voight — actually the T-1000 transformed — drives a blade-shaped arm extension through husband Todd’s mouth and skull, pinning him to a kitchen cabinet. The effect was one of many realized through a combination of computer graphics and mechanical gags.

Stan Winston’s contribution to the sequence was a strap-on blade arm that fit onto actress Jenette Goldstein’s shoulder. “The blade arm was made out of ABS plastic and fiberglass,” said John Rosengrant, “and it was much thinner than a real arm could have been. We didn’t want it to look like she was just wearing some kind of appliance on the end of her arm, so we made a full arm that was flesh-colored at the shoulder and then tapered down into a sword blade. The actress’ real arm was behind her back. We also made a bent-elbow arm that was puppeteered to swivel for a shot after she pulls out of the guy’s mouth and bends her arm at a ninety-degree angle.”

Though the various blade effects had initially been dismissed as among the easiest in the film, the makeup crew found them to be particularly painstaking. “A blade arm is not a difficult thing from a design and construction standpoint,” noted Winston, “but we found that once it had been vacumetalized, every single flaw in the sculpture showed. After numerous attempts to get it right, we finally realized that in order for the blade to really look like a perfect blade, it would have to be machined. So we had to back up and redo the entire process — machine the blades, attach them to the upper arm sculpture, then remold the entire thing and send it out to be chromed. Even after all of that, when the arms came back there would be glitches and we would see seam marks. So this blending of skin to chrome became a real nightmare. We wound up doing these things over and over again.”

For the shot in which the blade is withdrawn from Todd Voight’s mouth, Winston’s mechanical effects crew devised an elaborate mechanism worn by actor Xander Berkeley. “Originally it was just going to be a flip-up effect,” explained Richard Landon. “You would see the tip of the blade sticking out of the back of Todd’s head and then all of a sudden it would be gone when the blade was pulled out of his mouth. But we realized that Jim might decide to make the pull-out a slow, deliberate one, in which case we’d have to be able to control how quickly the tip pulled away. So we created a rig which clipped over the actor’s off-camera ear and then down to a shoulder harness which supported it. On the rig was a track that went around the off-camera side of his head. The tip of the blade rode on this track — scooting back and around Xander’s head.” During the shot, the actor leaned as far into the cabinet as possible to make it look as though the force of the impact had thrust him violently back. “He was in a really uncomfortable position — *and* he had a real spike going into his mouth as far as it could go. When it came time to pull the spike out, we first retracted the rig that went around his head. Then, a split second later, we withdrew the spike that was in his mouth. Viewed from above, the blade on the track would appear to travel forty-five degrees off the

path of the blade arm. Thus the blade continued to point towards the cabinet even as it moved to the side. The effect was rather striking.”



A telephoned warning from John arrives too late to help his foster parents — the T-1000 has already proceeded to their home and terminated Janelle Voight. Having reformed himself in her likeness, the emotionless killing machine next dispatches her unsuspecting husband with a metallic arm extension that darts out and skewers him through the mouth. The T-1000 then reconfigures into his familiar cop form, passing from his Janelle simulation through his intermediate transformational states in the process. The multistage metamorphosis was one of the most complex for the ILM computer graphics team.

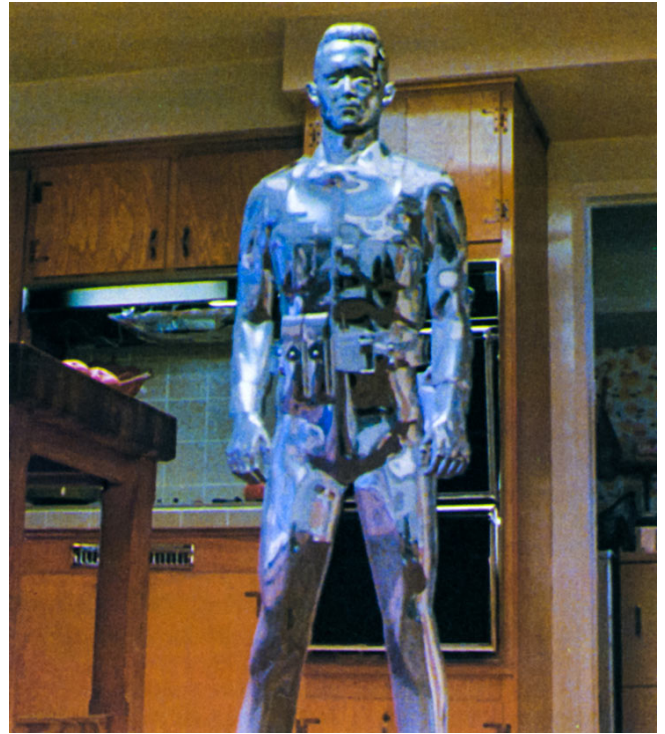


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Computer effects pick up the sequence as the blade returns to the shape of a human arm. In the live-action portion of the sequence, Goldstein held her real arm behind her body, moving her head and eyes as if watching the blade arm move in front of her as it changed shape. Much later, another woman's arm was filmed making the same movements in front of a bluescreen. The two elements were then put together in a traditional composite. "We shot the arm bluescreen," said Mark Dippe, "because we didn't want to have to deal with separating her arm from her body as it crossed in front of her." Model Interp was also used in the shot. "We modeled a blade and we modeled an arm," said Steve Williams, "and John Nelson used Model Interp between the two. Then we morfed between the live-action hand and the computer graphics hand to blend them." Reflections of Goldstein's face were added to the shiny blade to further tie the imagery into the scene.

After the blade has reconfigured itself back into an arm, the T-1000 transforms from Janelle into a female version of the Number Two chrome man — the smooth, featureless 'Oscar' statuette form — then into a larger, male Number Two and finally into a Number Three and Four before reassuming the now familiar cop form. "That was actually the most complex chrome transformation we had," said Dippe, "going from live-action Janelle to an Oscar-Janelle to an Oscar-Robert to a soft Robert to a detailed Robert to the live-action Robert."

The sequence also required digital puppeteer removal. "There were two cuts of Janelle moving her arm across the screen that were done with the blade arm that Stan Winston's crew had made," said Dippe. "There was a puppeteer wearing a black shroud crouched behind the actress' waist — and in the shot, you could see that shroud poking out from behind her thighs. To get rid of it, we painted in a clean plate — which had been shot just for this purpose — over the areas where the puppeteer was hiding." Doug Chiang corrected the plate digitally utilizing the Adobe Photoshop computer paint



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program which permitted him to accomplish hand-rendered touchup work one frame at a time.

“Photoshop enabled us to achieve perfect effects,” Chiang confirmed, “and we used it extensively throughout the show. Since it allows us to clone images from a clean plate, it is really more of a photo manipulator than an airbrush system. Some shots had little mismatches of mattes or other problems, and I could take care of those by hand on a frame-by-frame basis. It was very time consuming and it had to be done meticulously to avoid flickering in the image, but it worked very well.”

Aware that his foster parents are dead, John determines to spring his mother from the Pescadero State Hospital where she is a none-too-popular patient. Anticipating the move, the T-1000 arrives first at the facility, disguising himself in a variety of forms before assuming the shape of a corpulent hospital guard. The sequence begins with a floor-level closeup of the guard walking along a hallway surfaced with alternating black and white tiles. After his boots have cleared the frame, the camera lingers for a moment — and, suddenly, the T-1000’s featureless face pushes up out of the checkered floor. Originally, the computer team had planned to shoot a background plate of the floor for their computer graphics, then photograph the boots separately as a bluescreen element. Cameron feared, however, that with a locked-off approach to the shot, the black boots would not read well against the black-and-white floor. “We shot a tilt-down on the boots, instead — right there in the background plate — which meant that we had real shadows and everything,” said Muren. “Once we had done that, we started wondering if there was a way we could use this plate with the real boots — because it is always better to deal with real shadows and lighting instead of comping in a bluescreen element. This became the test shot for the development of ‘Make Sticky’ — a software program written by Tom Williams, one of our animation supervisors. Make Sticky was a way of taking a basic 2-D image and reshaping it with 3-D geometry — kind of like a morfing technique, except that it had a depth axis to it. It was something like

through his intermediate transformational states in the process. The multistage metamorphosis was one of the most complex for the ILM computer graphics team. Anticipating that John and the Terminator will attempt to free Sarah Connor from the mental hospital where she has been incarcerated, the T-1000 arrives just and assumes the form of a hospital guard. He does so by first replicating the checkerboard floor on which the man is making his evening rounds. Custom software was written to enable the T-1000’s featureless face to pull up out of the floor.



After rising out of the floor, the T-1000 takes the form of the man he is about to kill. Shots of Lewis the guard facing his perfect double were accomplished simply enough by engaging identical twins to play both parts. For a subsequent scene in which the T-1000 guard deploys a chrome finger spike to lobotomize his real-life counterpart, the makeup effects team constructed a partially articulated replica of actor Don Stanton. Shane Mahan makes adjustments to the puppet just prior to shooting.



The Terminator and John arrive in time to help liberate Sarah. When the T-1000 attempts to thwart their escape, the Terminator shoots him at point blank range, causing his liquid metal head to splash open. The initial stage of

texture mapping — which is a common CG thing — but the difference was that we could alter where we wanted the picture to grab and hold onto the geometry.”

the effect was accomplished with another Stan Winston puppet.

The plate of the tilt-down shot on the boots walking through the corridor was first scanned into the computer. “We took that plate,” said Jay Riddle, “and we front-projected the image directly onto a computer generated floor that matched the position of the original floor. With Make Sticky, we could make that front projection stick to the surface of the floor so that as Liza Keith’s animation of the head started to form and move up, the image of the floor distorted accordingly.” The following shot revealed a reverse angle of the head as it continued to rise. “We cut to a wider shot where Lewis the guard is at the coffee machine and behind him you see the edges of a kind of checkerboard apron around the T-1000 as it pulls up. The original plate that we used had Lewis standing there. Right next to him was a giant C-stand with a flag on it which blocked out all the light down at the end of the corridor. We completely replaced the floor in that shot with our own CG floor. Also, at the request of Jim Cameron, we widened the corridor by about a foot. After shooting the plate of Lewis, we moved the camera a foot to the left — keeping it aimed at the same vanishing point — and shot some additional footage that we used in the digital composite as our right wall. Then we composited our floor onto the real floor and had our T-1000 — animated by Rich Cohen — forming up out of it.”

The computer images were refined with yet another custom software program dubbed ‘Ray Samp.’ “Ray Samp allows us to build up a fabric around something,” explained Dippe. “If you took two spheres and put them in a nylon stocking, what you’d have would be a kind of dumbbell shape. That’s what Ray Samp does. It takes multiple objects and clusters them together and — in a kind of vacuform-style — forms around them to make a single shape. It was very useful for the shot of the T-1000’s face coming out of the checkered floor because the flat plane of the floor and the shape of the face were two different objects. With Ray Samp we were able to make the face gently slope to the floor. Without it, there would have been the flat floor and then suddenly the sharp edge of a cheek coming out of it.”

Actor Don Stanton, one of two twins who played Lewis the guard and his terminator clone, was scanned at Cyberware so that his features could be accurately modeled. “We did several scans of his head and used that data to build our model,” said Riddle. “Then, for the rest of the body, the computer sculpture of the Number Four Robert Patrick was reworked by animator Alex Seiden. Using side and front view photos of Lewis as reference, the Robert Patrick torso was beefed up to look like the heavier guard.” Because of the slowness of the shot, the figure had to be animated with a particular eye toward detail. “At first, when we plugged in all the animation to get him to rise, the result looked like something that was driven by a motor — it wasn’t organic enough. So we had to go back in and put in the subtleties of the head turning slightly and one shoulder lifting — creating asymmetrical motion to make it look natural.”

The last computer graphics shot in the sequence reveals the transformation from the Number Four Lewis to the live-action character. “You see this puddle of chrome on the ground which pulls in to join with the boots. Then the boots wipe to the live-action footage. Jim Mitchell match-modeled the legs and the boots for that shot. Because the polyalloy character was in contact with this distinct

pattern on the floor, Jim had to be very particular about how he placed him in the environment to insure that we would get the correct reflections. We had two people doing reflections all the time — Diana Ace and Alice Rosen. They worked on the Macintosh, retouching the reflection views and creating blends between the walls, floor and ceiling to make sure there were no seams or hard edges.”

After transforming into the guard shape, the T-1000 kills the original Lewis, lobotomizing him with a stiletto-like finger through his eye. Doug Chiang painted in the transformation of the finger turning into a spike — using the Photoshop paint system — while Stan Winston’s team provided the practical appliances which completed the effect. “We produced both a medium-sized and a longer spike,” commented John Rosengrant, “so that with cuts we could make it appear that the spike was growing. We also built a head-and-shoulders puppet of Lewis for shots of the stiletto actually sticking into his eye. It had some cable-controlled mouth movement and also some radio-controlled movement in the eyes so they could flutter and roll up. It took four or five people to operate it.” An eye mechanism had to be designed that would allow space through which the half-inch diameter spike could pass. “The inside corner of the eye is normally where we attach our eye mechanisms to the fiberglass core,” said Richard Landon. “But we couldn’t do that with this puppet because that was exactly where the spike had to pass through. Jon Price, who built this puppet, had to figure out a way to mechanize the eyes leaving that whole area free and open. He wound up making a heavy-duty mechanism that attached the eyes at the temples on either side of the head.”

Masquerading as the dead guard, the T-1000 searches the hospital corridors for Sarah — who has, only moments before, managed to escape her cell. Running frantically towards the hospital exit, Sarah comes face to face with the *Terminator*. Fleeing in terror, she is overpowered by the hospital guards until the cyborg plows in like a bulldozer and hurls them away. Suddenly the T-1000 — once again in his cop disguise — appears at the opposite end of the corridor. With single-minded intent, the liquid metal man strides down the long hallway, passing straight through a set of security bars. Several of the computer graphics teams had input into the shot before a successful technique was devised to achieve it. A reference plate was photographed of the empty corridor with the bars in place. Then the bars were removed and a second plate was shot with Robert Patrick. “In the second plate,” explained Doug Smythe, “Robert could actually walk through the area where the bars would be. We match-modeled our computer model of Robert to that footage. Once that was animated, we moved the model of Robert through the field of bars. Using Make Sticky, we could make the points at which the model intersected the bars distort accordingly. We were able to get about ninety-five percent of the way to a final-quality shot using this technique, but it still required some hand-painted touchup work by Doug Chiang.”

The *Terminator* fires repeatedly at the advancing T-1000 while making his way to the hospital elevator with Sarah and John. The elevator closes just as the T-1000 reaches it. Suddenly, two thin blades are thrust between the sliding panels, transforming themselves into pry bars which begin to force the doors open. “All that was shot for that,” recalled Dippe, “was the elevator doors opening — nothing else. We match-modeled the elevator doors and modeled the knife blades entering. The blades were then modeled and animated into pry bars and match-animated to open the elevator doors at the same rate they opened in the live-action. We also added some elements to make the

pry bars marry with the photography — like casting shadows and reflections from the bars onto the elevator doors.”

As the elevator doors are inexorably pried open, the *Terminator* sticks his shotgun through the widening gap and fires at point blank range, causing the T-1000’s head to split in half. The initial ‘*Splash Head*’ shots were achieved with two articulated puppets and an elaborate appliance worn by Robert Patrick’s stunt double. “The first *Splash Head* was a puppet that was used just for the initial shot of the head springing open,” explained John Rosengrant. “To construct it, we had first taken a lifecast of Robert Patrick in clay. That sculpture was split down the middle and pulled open. The splash was sculpted into it and the face on each side was reshaped and detailed. We made the puppet out of foam rubber, except for the actual splash part of it which was made from EST-40 — a light, yet solid urethane that has some flexibility, takes good detail and is self-skinning.” A fiberglass core was made for the puppet, then segmented on either side at the jaw line. Hinges were installed to facilitate the spring action. “Since the head was hinged on either side in two pieces,” said Landon, “we were able to tuck and curl everything into the inside of the head. We put a retaining cable through the two halves that could be released with a pin using a single pull controller. Because the first head was shot from behind, we were able to cover the seam by combing the puppet’s hair over it. Arnold fired the shotgun, we pulled the pin and the head sprang open and kicked back.”



Though temporarily disoriented, the T-1000 quickly reassembles himself with help from the ILM computer graphics team. A live-action plate of Robert Patrick was digitized and composited onto a computer model of the cop. That model was split open digitally and then reassembled via a custom software program directed to automatically restitch the severed facial vertices.

For the subsequent frontal view, a second, more detailed puppet was employed. “Our hero *Splash Head* was hinged at the same two points under each ear,” said Landon. “It had two lopsided eye mechanisms working independently of each other so that the T-1000 would look totally confused and out of control.” The puppet was also equipped with pulley mechanisms that could close the two halves of the head toward each other. “We installed sixteenth-inch-thick pieces of nylon with small cable risers on the edges of the splash so that as the hinged part of the head closed we could also draw in the splash.”

Finally, a *Splash Head* appliance was made to fit on Patrick’s double for a wide shot of the T-1000 staggering backwards as his head began to reform. To accommodate the sculpted appliance, the stunt performer positioned his own head as far back between his shoulder blades as possible. “The piece was attached above and in front of the double’s head,” Rosengrant explained. “He had to use a modified diving snorkel to breathe under it — the piece completely covered his face, neck and shoulders. Like the puppets, it was fitted with cables to give it some curling, closing action.”

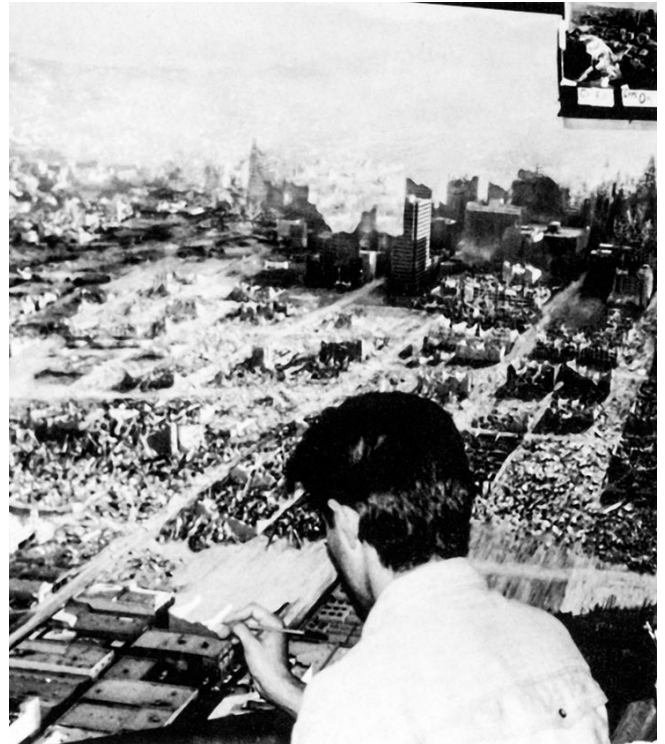
The computer generated closure of the *Splash Head* utilized live-action elements cut in with the computer image. “We shot a plate of Robert moving his eyes in a disoriented way,” said Mark Dippe. “We also shot a clean plate without Robert. Taking our computer model of Robert and lining it up perfectly with the live-action Robert, we then cut the piece of film of his eyes moving around out of the live-action. Using Make Sticky, we were able to put that little piece of live-action right onto the computer model. So we were able to put Robert’s face — which had the advantage of being shot in the actual environment — into the shot without having to do a bluescreen element.” John Nelson split the combined computer model of the head in half, then animated the closure.



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‘Chan Math’ — short for channel math — was a program employed for the final computer graphics element. “Essentially it was used to sew *Splash Head* back up,” stated Dippe. “There are many points of data to represent a face. If we had wanted to stitch the T-1000’s face back together by hand, we would have had to painstakingly go in there and stitch something like two hundred vertices. But with Chan Math we could say, ‘Start stitching here and stop stitching there,’ and it would stitch all the vertices in between. We also added another effect to that shot so that as the wound healed there was a little bit of chrome color in the seam which then faded in a wipe.” After much work, the computer team’s first attempts at the head closure failed to meet with the director’s approval. “Jim thought that our first shots looked like they came together by magic,” Dennis Muren recalled. “It seemed more like a camera trick than an organic thing. He said: ‘Don’t think of yourselves as *Industrial Light and Magic*. Think of yourselves as *Industrial Light and Dirt*.’ So we dirtied up the shot a bit. We added a scar to it — and later a camera shake.”



Matte artist Richard Kilroy at work on a painting designed to simulate Los Angeles in ruins.

While the T-1000 recovers from the blast, the *Terminator*-led trio makes its way to a lower level parking structure. Moments later, the T-1000 transforms into an amorphous blob and pours himself into the empty elevator through a hole in the ceiling. Animated by Rich Cohen, the shot bore a striking resemblance to the pseudopod effect in *The Abyss*. “What was tricky about that shot,” said Jay Riddle, “was that there were flashing lights all over the place. One fixture had lost its cover in all the shooting and another was swinging from one end. In order to match the lighting — since it was changing dramatically from frame to frame — Rich wrote code to analyze different areas of the background plate to see how the intensity and color of the light changed. Then he used that information to adjust the computer lighting of our T-1000 blob as it was coming down through the ceiling.” Cohen also animated the following shot in which the blob drops from the ceiling and forms into the Number Two chrome figure.

The Number Two figure exits the elevator in the parking structure just as Sarah, John and the *Terminator* drive away in a stolen police vehicle. With superhuman speed, the T-1000 runs after the car, transforming back into the live-action Robert Patrick as he does so. The running chrome man shot — animated by Jeff Campbell — utilized many of the principles of execution that the computer team had discovered for the shot of the chrome man walking out of the truck fire. “It was a very dynamic shot,” said Dippe, “and it required all of the techniques we had previously developed. We shot many takes of Robert running, with our dual cameras tracking his stride to help us match the action with our computer model. The shot had to be very carefully animated and rotoscoped so that we could reveal the live-action character at the end correctly.”

As the T-1000 catches up to the getaway car, his arms transform into a pair of crowbars which enable him to attach himself to the rear of the vehicle. Some shots for the sequence were achieved simply enough with a Robert Patrick dummy — complete with crowbar arms — lashed to the back of the car and shot on location. Equally simple were insert closeups of the metal hooks tearing into the prescored trunk. Several shots, however, required Winston appliances worn by Patrick and shot on a process stage. “We wanted the crowbar arms to look as thin as possible,” Rosengrant stated, “yet we still had to hide a human arm in there one way or the other. So we sculpted two different versions of the crowbar arms — a top view and a side view — which would show just the thinnest part of the arm from either angle. If we had just sculpted one for use from any angle, it would have been very thick and clunky. We made at least four of each version because they really got trashed during filming — slamming into the car and knocking out windshields. They took major abuse.”

Losing his hold on the car, the T-1000 is separated from one of his embedded metal hooks which John pulls from the trunk and throws into the street. After a moment, the severed hook loses its shape and becomes a blob of polyalloy. As the T-1000 approaches, the blob begins to inch toward him and is eventually absorbed into his shoe. “We had thought the shot would be simple because it was just a blob,” said Jay Riddle, “but there were a variety of techniques we had to use to make it look like it was really in the environment. There were a lot of lighting changes in that sequence. At first the hook was out in the middle of an open area; but by the end of the sequence there were feet on either side of the blob blocking the light from both directions. There were also shadows to deal with. We had to match-model the geometry of the shoe so that as it moved in you would actually see highlights and reflections blocked out on the surface — as if the shoe was casting a shadow on the blob. We also had to add the reflection of the blob on the ground and the shadows cast by the blob as it slid toward the shoe.” Animator Annabella Serra created the movement of the chrome blob as it moved toward the shoe and joined with it.

Temporarily free from their pursuer, Sarah, John and the *Terminator* head for a mercenary training camp in the desert where Sarah had learned many of her military skills. En route, the trio makes a stop at a closed auto mechanics shop where Sarah and the *Terminator* tend to each other’s wounds. In a scene cut from the final film, Sarah also performs ‘brain surgery’ on the *Terminator*, extracting and altering the computer chip buried deep within his cranium and enabling him to learn beyond the limits of his terminator programming.

Because Cameron wanted the camera in tight on the *Terminator*’s head as Sarah cut into the skull and pulled out the chip, a puppet head was obviously required. To create this particular puppet, a bust of Schwarzenegger was sculpted in a specific pose. “*The Terminator* was going to have his head tilted down and his eyes looking up into the mirror,” Winston explained, “so we had to sculpt a head in that particular attitude. If we had just taken a generic Arnold puppet head and tilted it down and made the eyes look up, it would not have looked right; because when you actually assume that pose, your brow furrows, the skin around your neck changes — all of that subtle change has to be sculpted right into the puppet.”

After the puppet had been sculpted and molded by Greg Figiel, the finished fiberglass core was delivered to the mechanics team. “We cut out the eyes and cut the jaw free so that we could incorporate the various mechanics,” recalled Richard Landon. “Charles Lutkus, who did the majority of the construction on the head, was given a copy of the chip that was going to be put inside so he could provide an area for it. He built an eye mechanism — also mechanisms to articulate the lips and jaw and eyebrows. All of those articulations were radio-controlled. Then, for the gross head and neck movement, we simply cut a hole in the center of the puppet’s back so that an operator could duck down behind it, stretch his hand up inside the head and grab a handhold which ran between the ears.”

Shooting the surgery scene was accomplished using both the puppet and Schwarzenegger. The camera began in close on the puppet head to reveal the open flap, the crater inside the skull and the computer chip. Then it dollied around to reveal a mirror in which the *Terminator* was watching the proceedings and giving instructions. “We had a mirror frame with nothing inside it,” explained Van Ling. “On one side of it was the puppet and on the other side sat Arnold. They were facing each other so that it looked like Arnold was looking at himself in the mirror. We also had Linda’s twin sister on Arnold’s side, mirroring Linda’s movements on the puppet. Eddie and his double were also in the shot. Jim directed them with counts. To sell the effect, the art department had built a portion of the garage set in reverse to put on the other side of the mirror frame. We embellished it by putting objects on the table that could be mirrored on the other side — a Pepsi can and a pile of nails — anything to help the audience accept that it was a mirror image.” Even Schwarzenegger’s makeup had to be applied in reverse.

Arriving the next day at the desert encampment, Sarah and the *Terminator* proceed to arm themselves from a weapons cache buried underground. Wary and afraid, Sarah falls asleep and experiences the nuclear war dream which has haunted her



The nuclear blast radiates outward from ground zero. An aerial photograph of downtown Los Angeles was enlarged to a six-foot-wide print and retouched somewhat for clarity by matte artist Rick Rische. A sheet of clear acetate was then placed over the photo and a corresponding painting of the city in ruins was rendered by Rische and Richard Kilroy. Foreground imagery of a hillside home being demolished by the blast was photographed in miniature against a black background. Computer generated elements of the nuclear dome and shock wave effect — also of downtown buildings being struck and crumbling — were produced at Electric Image. On stage at 4-Ward Productions, the disparate elements of the multipass shot were assembled using a beam-splitter, three rear process projectors and a physical wipe from one painting to the next.



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for ten years. As conceived, the dream — which was realized through a combination of miniature and physical effects — was a stylized vision of apocalyptic reality. “I wanted it to be absolutely vivid,” said Cameron, “but also more real than possible. The scene oscillates between a photorealistic, almost documentary quality and stylistic elements. The stylized component is that Sarah is still an observer when she should be dead. How can you stand there and watch a nuclear war? You can’t. So it’s a God-like dissection of the event — and yet it still feels subjective. It was a very hard thing to find a visual, narrative line through because the event is essentially unwitnessable.”

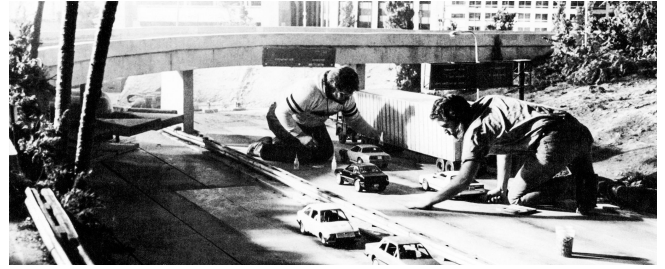
4-Ward Productions — headed by Robert Skotak and Elaine Edford — utilized a wide range of techniques to produce the seven shots which, intercut with Stan Winston puppet effects, would comprise the more graphic elements of the dream. “The nuclear war shots are physically brutal with massive amounts of light and energy,” stated Skotak, who served as visual effects supervisor. “They are intended to make you actually *feel* the tremendous power and terror of nuclear war. The underlying message of the dream is: ‘Here is an environment you are familiar with — here is what would happen to it in a few split instants. So beware.’”

As research for the project, Skotak and his brother, Dennis — who served as supervising director of photography — studied government footage of actual nuclear tests, as well as simulated nuclear explosions attempted in previous films such as *Invasion U.S.A.* and *The Day After*. “The idea was to take that nuclear test footage — most of which was shot in the desert — and adapt it to an urban environment with skyscrapers and houses and freeways. One of the things that appealed to us about the project was that we were given quite a bit of freedom in designing it. Dennis and I went around and took a lot of photographs all over Los Angeles and then chose areas that we thought would work, drew up storyboards and showed them to Jim. We, as well as Jim, wanted to do more than just show buildings being destroyed, so we included scenes with a freeway overpass and a park. All of that together made it a more interesting sequence. We had never really seen a nuclear shock wave travel through a city before.”

4-Ward’s first shot in the sequence — the only one which incorporated actors — started on a tranquil, sunny playground crowded with children. Suddenly, a flash of white light appears behind the distant city skyline. To obtain the desired plate material, Vistavision footage of the playground was shot at two different times of day — morning and afternoon. By beginning with the broadly lit morning material, then going to a brilliant white-out and dissolving into the backlit afternoon footage, the sun itself would provide the predominant light effect. But that simple notion became quite complicated in execution. “The idea was that the buildings in the background would be silhouetted in the second part of the shot — since the blast was behind them — but on the day we shot, the foreground actually turned out to have darker characteristics than the city skyline, which was very light. We wanted the sand in the playground to be very hot, so we had to do a lot of optical manipulation involving separations and masks to whiten up the foreground part of the shot and darken the skyline. I worked closely with Dave Hewitt and Larry Alpin of Hollywood Optical Systems in making all the pieces blend.”

Although the original plan had been to simulate the blast with an instantaneous burn-out of the frame, after viewing the initial tests, Cameron determined that the shot needed something to heighten the impact. “Jim wanted to see something more kinetic happening with the blast, like a

core of white light in the sky that would move forward in the shot. That required rotoing two of the frames and creating some artwork.” Additionally, the Skotaks created a white-hot nuclear cloud to composite into the shot. “We made a plexiglass column — a half-cylinder about eight feet tall — and covered it with a couple of layers of fiberfill which we backlit. To create a sense of upward motion, the fiberfill material was made to rise at different speeds with a few simple wire gags. The cap of the blast was a mechanical rig designed by Joel Steiner that consisted of two big plexiglass disks rotated by pulleys and then four secondary disks — all covered with fiberfill and backlit so there was a hot core. Behind them, we also had rotating gels — rigged by Mark Shelton — to suggest a fiery crawl. The effect was shot at about sixty frames per second and framed so that only the lower part of the cap was visible in the shot.”



Modelmakers Brian McFadden and Louis Zutavern dress a stretch of miniature freeway in preparation for another nuclear blast shot. Hooks passing through invisible slots in the roadway were connected to the undersides of the cars and trucks and were drawn along by a pulley system. Air cannons were focused precisely to blow specific vehicles off the road.



Visual effects supervisor Robert Skotak adds final detailing to a breakaway bus traversing an overpass.

“The tricky part,” said Dennis Skotak, “was that the nuclear cloud itself was a light source, and yet it still had to be seen and defined against a light sky. So we had to make it stand out and yet still blend in. It was a matter of finding the right combination of gray density to define the shape of the cloud while retaining its predominantly luminous characteristic and still be able to make it stand out against a light sky.”

“Also,” Bob Skotak observed, “we were forcing the events to occur faster than they actually would because of the brief nature of the cut. We looked at tapes of every nuclear explosion that had ever been shot and there was always a die-down time. Things just kind of white-out and you don’t see anything for a while. Then the sky darkens and darkens and gradually defines the mushroom shape. The column actually has no luminosity — it’s the ball above that does. We had to play around with that since the cap, because of the widescreen format, was mostly out of the frame by the time it became visible at all. So we had to put a lot of luminosity in the column and still define it as a nuclear bomb shape by making the cap darker than normal. All of this had to happen in about a four-second cut.”

The initial long shot would be followed in the film by closeups of adults and children on the playground bursting into flame as the thermal blast wave sweeps over them. “There was a lot of smoke in those shots,” Bob Skotak continued, “and Jim decided, after he cut the sequence together, that we should add smoke to our shot to tie it all in. So we laid out duvetyne on the floor — in about half the scale of the real location — and shot some smoke using a lineup clip on the live-action plate to place it in specific areas of the shot. The idea was that there was moisture in the ground or in the air that was condensing into vapor from the initial heat before it got so hot that everything actually ignited. The whole shot was very, very difficult because it was really all about matting light values and having one light value take over for another with a lot of cross-fades. We went through a great many variations to get just the right balance.”

Following the initial blast, the sequence cuts to a high-angle view of downtown Los Angeles being decimated by the nuclear shock wave. The original intent was to shoot a still plate from the desired vantage point and then create a post-blast matte painting in perfect register that would wipe over the original plate as the shock wave radiated outward. Miniature breakaway buildings representing the downtown business district would be blasted to bits with air cannons and the footage optically incorporated into the painting. In the foreground would be a hill and a larger-scale miniature home that would also be destroyed as the shock wave reached it.



It was not until after the miniature was constructed that James Cameron requested that the entire sequence be flopped to reverse the screen direction of the blast 4-Ward was able to accommodate by shooting into front surface mirrors — though first they had to reverse the traffic flow, switch drivers’ sides of the vehicles and flop all road signs. Supervising director of photography Dennis Skotak makes adjustments to a cluster of cameras and mirrors.

The foreground element was the first to be accomplished. Three twelfth-scale, breakaway houses were built by model-maker David Zen Mansley to enable multiple takes. “They were fairly large miniatures — about three feet wide and eighteen inches tall, and very detailed,” said Bob Skotak. “They had interiors with furniture and flower pots and glasses on the table — everything. We had picked twelfth-scale partly because we could get doll furniture at that scale, which helped. We scored the entire house with razor blades so that it would break apart in a somewhat ideal way. We also had to dress the inside so that when the house broke apart you wouldn’t be able to see pieces of tape or supports that were holding parts of it together. Every piece that held something together had to be disguised to look like it was actually a functional part of the house. Also, we had to build the miniature trees so that they would blow over and flatten out. And the car in the driveway had to be jacked up ever so slightly so the wind would catch it and blow it away. It was really tricky — scoring and dressing the thing took four or five guys all day.” Once the miniature was readied, the hilltop set piece on which it was sitting was positioned on stage against a black background. Five high-powered air cannons and a Ritter fan were placed in the darkened matte area and the shot was photographed at high speed, then set aside for future compositing into the sequence.

The Skotaks next concentrated on getting their panoramic shot of downtown Los Angeles. “We went up into the hills around the city — the highest vantages we could get — but we couldn’t find anything that would give us the perspective Jim wanted,” Dennis Skotak recalled. “So we finally rented a traffic helicopter and had cameraman Tai Salamatti go up and shoot a series of test photos. After we selected from that reference material, he went up again and shot a specific area on large-format film and got exactly the angle and lighting conditions we needed.”

A six-foot-wide print was then made and retouched to fulfill the requirements of the shot. “Rick Rische painted in some modifications,” said Bob Skotak. “In the photograph, for example, the buildings looked like a solid wall — there was little separation between them. So Rick airbrushed out some of the buildings and simplified them so that the skyline was a little more discernible as to what was a building, what was a street, what was a park. After that initial retouching on the print, he put an acetate overlay on it and, together with Richard Kilroy, did quite an elaborate matte painting of that entire terrain in ruins — buildings stripped down to girders and foundations with rubble in the streets. We could flip the acetate up and see a normal city, then lay it down and see that same city in ruins.”

Meanwhile, demolition tests were under way on a number of small-scale breakaway skyscrapers. “The buildings were about eight to ten inches tall and we shattered them with little triphammer-type things and shot them at a hundred twenty frames per second. They looked pretty good. We set up one in silhouette through a beam-splitter lined up with a painting of the city. It was backlit hot so that once we shattered this little breakaway model, the building seemed to disappear — it just got burned out by the light that was double-exposed on top of it.”



Also included was a shot of a wooded park being hit by the blast. Dozens of miniature trees were fashioned and

Though the tests produced positive results, the prospect of satisfactorily destroying large numbers of miniature buildings was daunting; so the Skotaks began searching for a less labor-intensive approach.

Thinking that computer graphics might be a

workable option, they contacted Jay Roth of Electric

Image. "I said to Jay, 'Look, we've been experimenting with shattering little breakaway buildings and they look pretty good; but to do forty of them is a big project. Look at our test footage and see if you think you can duplicate it.' We thought that if we could generate the elements of the collapsing buildings and the nuclear blast dome in their computer, we could then put the shot together through a beam-splitter with the matte paintings and enjoy a great deal of control. Jay showed us some tests that were promising; and ultimately we committed ourselves to doing it with computer graphics."

An 8x10 transparency of the pre-blast cityscape was first scanned into the computer at Electric Image. "Using that photograph, Jay and Allen Manning were able to build a computer model of the city. Basically, the key part of the image encompassed an area that was about a mile and a half in circumference — beyond the Harbor Freeway from the downtown area and into the hills that surround it. They had to locate that actual area in three-dimensional space and find out from the city planner how tall all the buildings were — each and every one of those buildings in the photograph. They also used a Thomas Guide of the city to help them with the street layout. Our combined efforts resulted in a complete model of Los Angeles built in a computer from our specific point of view." Employing a custom explosion program written by Mark Granger, animator Markus Houy was able to simulate the effects of a nuclear shock wave on the computer model of downtown Los Angeles. "We gave Electric Image sketches of how we wanted the breakup to look — an initial impact and then a slow crumbling of the buildings. They were able to generate different speeds for us, different gravities, different scale pieces. And they produced a lot of tests very quickly, so we were able to fine-tune the look."

Electric Image also generated the glowing plasma dome and the shock wave ring of the nuclear explosion. "The shock wave was coincident with the leading edge of the dome, which also had the element of the buildings breaking in it. So the two were exactly matched, one for one. The third element they provided was a shaded pass that added some light and dark features against a black field. It was edge lighting on the shattered pieces that were falling — just a suggestion because basically the buildings were in silhouette. Its purpose was to improve the graphic look of the shot."

The three elements generated by Electric Image were converted to registered film prints which could be put into a process projector during the multipass shot assembly. "We used three process projectors feeding in from different angles — one for the rear screen, one for the house projected on a white card in front of the city painting and one for the final blast. We projected the registered prints into a rear screen, and we set up a beam-splitter so that we were looking at the matte painting — the six-foot print of the normal city — and through the beamsplitter we could superimpose any of those three elements, lining them up with the painting so they were in exact registration. In effect, we had a traveling matte that was wiping across the photograph of the city as it was being destroyed by the computer generated elements." The wipe was accomplished

connected to a network of wires rigged to pull them over on cue when the requisite air cannons were triggered. Inter-cut with the miniature footage were scenes of Sarah Connor reacting in horror as she watches a playground full of children being incinerated by the nuclear blast of the takes. Fire was inserted into the shot as a separate element that ignites herself. Makeup effects crew members score the charred skin of one of the Sarah puppets created for the sequence.

physically with a blade. “The blade was curved like the dome and came across the shot. It covered the image in front while, in the beam-splitter, the new image was coming in.”

Numerous passes were required to achieve the final shot. “In a sense, what we did was create an enlarged optical printer on our stage,” said Dennis Skotak. “We could use it to manipulate individual elements and fine-tune them with shading and shadows and additional lighting in places on the painting. It gave us the flexibility of a printer, but with a lot more nuances. Being able to go up and actually change the edge of a matte ever so slightly gave us great control over the whole process.”

Although Cameron was initially very pleased with the shot, after running it at half-speed he decided he would prefer the blast to expand at a slower rate. It was too late to go back and regenerate all the computer elements, so optical supervisor Robert Costa was tasked with devising a suitable solution based on the existing footage. To extend the shot without merely double-printing individual frames, Costa opted for a ‘cascading’ effect. “I have a computerized printer and a program that allows me to print a number of frames onto the same frame of film — each at partial exposure. It’s like doing constant dissolves — fading out of one frame and fading into the one that’s coming up next. But in this case, I went beyond just the two frames that were involved — I went several frames in both directions. After trying different combinations, I came up with a formula that entailed fading in three frames, fading out three frames and then winding back four frames. That way, the shot was made twice as long, but without duplicating any one frame. By dissolving together a number of frames, the cut between one frame and the next was softened into a kind of blur. If you looked at a single frame, it would have overlapping images on it — but the overall effect was a slight blur. You can do the same thing manually, but it is extremely tedious. With the computer, I could just tell it the pattern I wanted — how many frames and how much exposure — and let it run.”

For additional closer views revealing the disintegration of the city from street level, a replica of downtown Los Angeles was built in scales ranging from one-sixteenth in the foreground to one-thirty-fifth deeper into the shot. “The buildings were modeled after actual buildings on the corner of Figueroa and 2nd Street looking west,” said Dennis Skotak. “They are not identical, but they are pretty close. We had to simplify them in some areas and add detail in others. They were built by Steve Brien and Ricc Ruskuski who used welded steel stock with pencil-rod cross-members for the basic structures. On top of that we cast hundreds of breakable resin girders. One of the biggest challenges of the whole setup was finding an outer building material that was fragile enough to break in the right-sized pieces for scale, but at the same time strong enough to support itself. The concoction we came up with was pyrocel and plaster, gypsnow and vermiculite. Then wires were laced in the middle of it — which were meant to look like rebar when the building broke apart — so that we would have something to tie pull wires to.”

Detailing of the buildings — which averaged five feet tall — extended far beyond the external surfaces. “Behind the facades,” said Bob Skotak, “there were hundreds of little predestroyed rooms filled with soft plaster and balsa wood — even corn flakes and matzo crackers — anything that would break away and shatter. We had to detail all the way to the backs of the buildings because there was no way to tell exactly how much was going to get blown away. So we put in everything — rooftops and little rooms. And anything that we used to connect one piece to another had to be dressed, too. Tens of thousands of pieces, literally, had to be dressed for this miniature.”

Originally, the plan had been to orient the buildings with their front surfaces facing upwards to capitalize on the natural pull of gravity. Preliminary tests, however, indicated that the advantages of this approach were far outweighed by the disadvantages of rigging and lighting the setup from above. Consequently, the decision was made to erect the structures in a traditional upright manner. “Each facade was rigged with a dozen or more wire pulls attached to a squib release. Hundreds of pounds of sandbags were connected to them. Joel Steiner and Joe Viskocil engineered these pulls and weight-drops, and rigged the backs of the buildings. Facing the buildings were ten air cannons and two Ritter fans, plus two air lines and an E fan. Moments after the cannons and the fans were triggered, the sandbag releases would be tripped and the buildings would be ripped backwards. Timing was critical since there was a certain amount of delay from the time the air cannons and fans were turned on and the wall of air hit the buildings. We had to make sure we didn’t trip the weights too early or too late. Our two gaffers — George Neil and Mark Shelton — performed miracles during the shoot. Because these were *nuclear* explosions, we had to have a tremendous amount of light; and they did a great job of jamming a lot of very hot lights into sometimes restricted areas while maintaining even illumination throughout.”

Three cameras recorded the action at one hundred twenty frames per second — and eight separate takes were needed to get just the right results. Each successive take required a full rebuild on the set — and each rebuild required up to three days of rerigging and redressing the models. “One of the refinements we came up with — at Jim’s request — was adjusting the air cannons and the pulls so that the buildings collapsed in sequence, from the back of the shot to the front, rather than collapsing all at once. Dramatically it was better. To do that, we calculated the timing and fired the air cannons and tripped the pulls in sequence off a computer board.”



Laser scanning was employed to produce a styrofoam bust of Linda Hamilton screaming. Using this bust as the basis for a finished sculpture, the Stan Winston team created three separate puppets for the nuclear war dream. The first had facial and arm articulation and was capable of basic body movement. Flammable rubber cement was applied on the set and the puppet was ignited electrically with squib sparks.

Additional elements were added to enliven the wide-angle shot. Cameron suggested that a car flying by in the foreground would add some visual interest. “We thought seriously about doing it all in place at the same time; but that was a very complicated element and we wouldn’t have been able to predict exactly what it would do. So rather than chancing it, we shot the car as a separate bluescreen element and laid it into the shot. The car was an off-the-shelf, eighth-scale model that we dissected and then wired back together loosely — so it was like a floppy car. We filled it with loose parts and launched it across the set, blasting it with an air cannon. We had to do twenty-some takes on it — demolishing the car each time and then wiring it back together.”

Other elements were also inserted. “Joe Viskocil blacked out a section of our stage and shot separate fire elements on a very large fire bar. They were primarily foreground elements — fire on the pavement, an ignited bush — and those we combined optically. We also shot smoke coming up the faces of the buildings as a separate element. To do that, we blacked out the buildings and had foggers under the set. The set was on a raised platform and there were slits along the front edge of the buildings — a kind of vent system through which the fog could rise and travel right along the front surfaces. We blacked over the fronts of the buildings with black velvet flats and hot-lit the rising smoke. These elements were later burned into the shot.”

Not all of the shots were distinctly urban. One — a Los Angeles park setting — entailed the construction of dozens of miniature trees capable of bending and twisting violently. Designed and engineered by Joel Steiner, Michael Novotny and Steve Sanders, the sixth-scale miniatures were pulled over by a network of wires rigged at the side of the set. “There was also a telephone pole in the foreground that was partially made out of tree bark — which turned out to be great breakaway material,” said Bob Skotak. “It was about six inches in diameter and we filled it with some dry birch bark we happened to find out on location. The outside of the pole was a PVC tube that had been cut in a serrated pattern and then dressed over with plaster and caulking. It was hinged so that when we pulled back on it, all of the overlapping bark inside would snap.” Like the other blast shots, the park setup required a complex interaction of wire pulls and forced air effects. “Jim Belkin — who was ordinarily our cameraman — had the thankless task of pulling the telephone pole over in exact sync at sixty frames per second. It was a scary job because if he botched it, it would mean a full day to rerig the set. But he hit it right on the button — and on every take!”

Fire was also added. “We elected to put fire behind the second tree into the shot, so we rotoed the tree in the stationary frame and photographed a fire bar at a fairly large size to go behind it. To make the foreground telephone pole appear to be on fire, we shot a separate element of a log on fire and just counted frames and figured out the speed at which it should be blown over to match the previously shot action. We had air cannons aimed at all of these fire elements so that it would look



The final image of the dream has Sarah clinging to a chain link fence as her flesh is turned to ash and blown away by the nuclear firestorm. A paper-thin casting of Hamilton was placed over a reinforced skeleton and then packed with shredded gray and black napkins. Air mortars were used to blow both the skin and the simulated ash off the skeleton.

like the fire was being mowed down by the blast. The moment the blast occurred, the fire got knocked out of the shot.”

Nothing says Los Angeles more succinctly than a crowded freeway, so it seemed only natural that one of the representative bomb blast shots feature such an image. Constructed for the shot was a four-lane freeway — complete with sweeping overpass — trimmed with ground vegetation and palm trees and nestled in a cluster of office buildings. The eighth-scale set measured thirty-five feet by forty-five feet and was crowded into one of the secondary 4-Ward stages. “We modeled it off the Harbor Freeway at 2nd Street,” stated Dennis Skotak. “Steve Brien and Ricc Ruskuski engineered the traffic movers which were essentially pulley systems driven by motors on both ends of the set. Little hooks traveled through invisible slots in the roadway and connected to the undersides of the vehicles. It was a tricky problem to get them up to speed because we were shooting at sixty frames per second. Lou Zutavern, Tim Conrad and Brian McFadden worked on the vehicles. We used some off-the-shelf cars and also molded a few from a previous film we had worked on. It was important that the cars break and bend convincingly. We scored them, made crushable rooftops by cutting through their mullions and backing them with lead wire so that when the wind hit them they would bend sideways. The basic chassis were made doubly strong so that they could sustain the force of ten air cannons aimed at them. Lou Zutavern made a custom bus. The entire roof was fabricated of thin sheet lead so it would peel off in the wind. For the bus windows we used squares of very fragile microscope slide cover glass.”

Air cannons positioned at strategic locations were focused precisely to blow specific vehicles and signs off the road — and in some cases, up the adjoining freeway embankments. The palm trees — which did not have enough surface area to be blown over — were rigged with wire pulls. Like the downtown street scene, the freeway shot would require a number of exasperating retakes.

“Something would invariably spoil the scene,” Dennis Skotak noted. “At one point we had a perfect shot going and then a blast of air caught one of the slots in the road and peeled the pavement right off — and it had been contact-cemented and screwed down tight. Eight times we rerigged that set. We would decimate it entirely and then have one day in which to totally rebuild it. Everybody would wander around the set looking for little eighth-scale dead bodies and pieces of their particular sign or vehicle. Generally we’d find most of the pieces, but some of them had to be rebuilt. So we’d superglue everything back together again. Actually, we found that the takes became more interesting as we went on because the miniatures began to acquire a lot of bends and dents — things you’d find in real cars and street signs.”

All of the miniatures for the sequence had been completed when Cameron — due to live-action changes — requested that the action of the nuclear blast travel in the opposite direction from the one in which the sets had been laid out. “Jim asked us if we could flop the entire sequence,” said Bob Skotak. “There was some momentary panic; but luckily, we found a way to shoot it into a front surface mirror. What it entailed was flopping various things like the traffic signs and the drivers’ sides of the cars. We also had to switch the markings in the road and the traffic flow; and in the case of the tree shot, there was a stop sign that had to be flopped.”

In addition to the miniature blast effects, 4-Ward Productions also produced footage of a large-scale nuclear simulation. Supervised by pyrotechnics expert Joe Viskocil, the fireball was originally intended to be used for a sequence at Cyberdyne Laboratories when computer scientist Miles

Dyson, near death, envisions the nuclear holocaust he has given his life to prevent. When the Dyson vision was cut, the footage was incorporated into the opening title sequence.

After considering briefly the idea of staging a modest explosion on one of the 4-Ward stages, Viskocil — together with effects producer Elaine Edford and cameraman George Dodge — opted instead to drive out to the El Mirage dry lake bed in the western Mojave Desert. “We set up fourteen steel mortars in a circle about sixty-five feet in diameter,” said Viskocil. “Jim had asked that we shoot off thirty or forty gallons of gasoline; but I thought, knowing Jim, that I had better double that. We were out in the desert where it was very safe, so we set off a gigantic explosion that was sixty-five feet in diameter at ground level and spread out to about eighty-five feet across once it went up. The fireball rose approximately two hundred fifty feet in the air and was so big that some residents in the area called the police and fire departments because they thought a jetliner had gone down.” After a daytime test, a series of night blasts were detonated — each disrupted to a greater or lesser degree by winds gusting up to fifty miles per hour that tended to dissipate and blow the fiery mushroom cloud off course. On the fourth highspeed take — captured skillfully by George Dodge — a satisfactory image was achieved. “It was amazingly hot. We were eighty feet away from the explosion and we could still feel the heat from it. We shot it at three hundred sixty frames per second, so we got an awful lot of footage out of it — with billowing clouds and everything, which is exactly what Jim wanted.”

Sarah, a helpless witness to the Los Angeles blast, lets out an anguished scream, and in an instant is turned to ash which subsequently blows away and reveals her charred skeleton beneath. Three Sarah puppets, constructed by the Winston crew, were required to achieve the effect. Because the sequence called for a horrified expression — difficult for an actor to sustain for the length of time required to take a plaster lifecast — Winston opted to have Linda Hamilton scanned by laser at Cyberware and the data output in the form of a styrofoam bust that served adequately as the basis for a finished sculpture.



The T-1000 trails his quarry to Cyberdyne Laboratories where the trio has managed to destroy the nascent technology that would otherwise have propelled the world into nuclear Armageddon. When the fugitives escape in a SWAT van, the T-1000 responds by driving his motorcycle through a second-story window and into a hovering helicopter. Clinging to the aircraft, he smashes through the canopy and — in his metal blob form — pours himself through the opening and into the cockpit.

The scene begins with a shot of Sarah with her arms across her face. As her arms come down, she ignites into flame. The puppet used for the first part of the effect was a waist-up duplicate of Linda Hamilton with articulated arms. “We built a ball-and-socket armature with joints for either shoulder that we then drove with cables to get the reveal of her face as her arms moved away from it,” said Richard Landon. “The puppet had jaw articulation, as well, to suggest Sarah’s scream. There was also a hard-drive linkage in the back and a stainless steel, flexible hydraulic hose in the neck that was cable-driven to produce a basic body motion as she is hit by the impact of the blast. We built a box that went under the puppet and I put on a kevlar fire suit covered my hands and my hooded head with fire gel, and rocked the puppet back and forth on its waist linkage as the entire set was set on fire. So I was right in the middle of all of that fire — which was an interesting puppeteering experience.”

The next stage puppet was a charred version of Sarah hanging onto the chain link fence as she is further engulfed in flame. The figure was covered with flammable rubber cement and set on fire electrically with squib sparks. “Her fingers were already locked onto the fence, so the motion of the body provided everything we needed. Stage Two also had jaw articulation and a mechanism that kicked the head back with a rigid linkage. Because we were burning the puppets, we couldn’t count on wire under tension to hold up in that hot atmosphere; so just about everything in the Sarah puppets had to be hard linkages — especially Stage Two which was in flame from beginning to end. We got away with a few cables on the Stage One puppet only because there was just a brief moment of impact with the flames. If the puppet fell apart after that, it didn’t matter.”

A tremendous amount of research and development went into the third Sarah puppet — an ashen form which blows away to reveal her skeleton underneath. “The third stage skeletal puppet was Shannon Shea’s shining moment,” Landon continued. “He researched, developed and built the entire effect pretty much singlehandedly — with help from our lab staff. We took a medical



ILM visual effects supervisor Dennis Muren confers with shot supervisor Jay Riddle as they view one of the computer graphics shots generated for the sequence.



Among the most difficult shots to produce was one in which the T-1000 — in his chrome cop form — was required to speak a line of dialogue. Sequential laser scanning was used to produce digital imagery of Robert Patrick forming the specific facial articulations his computer generated counterpart would need in order to achieve proper lip-sync.

demonstration skeleton that we bought out of a catalog and then had one of our guys weld up a steel armature to go inside, just to reinforce it. Then the skeleton was assembled in the same position as the last position the Stage Two Sarah was in so that there would be a proper cut. Next we laid tissue paper and tempera paint into the mold of screaming Sarah. Once the paint dried, the fragile skin was carefully pulled out and placed over the skeleton like papier mache. Then shredded gray and black napkins were packed inside of it. We found the quickest and easiest way to shred them was to just stick them into a blender for a few seconds. After that was all packed in, we used an X-acto knife right before they rolled camera and scored the heck out of it so that there was virtually no structural integrity at all to the skin. The special effects team blasted it with air mortars they had set up and the entire skin was blown off the skeleton. It is a very creepy effect — the skin just vanished and the tissue paper inside swirled away like ashes floating in the air.”

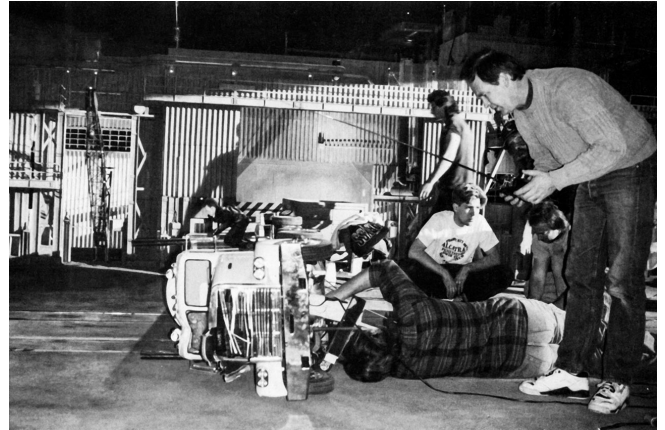
A similar ash effect was used on an assortment of dummies built especially for the sequence. “There was a dummy of Sarah holding her child that ignited and exploded into flame,” said John Rosengrant. “Those were just static — dressed and set on fire. There were also some ash children in the playground area — little kids that had been charred, kind of like Pompeii victims. For the dummy Sarah and her son, we used the same shredded napkin technique for the inside, but with a different exterior. It was a rigid polyfoam that had water put into the mix so that it was weakened and very crumbly — like ash. This polyfoam was mixed with a little black and gray paint and then poured into a big silicone mold, hollowed out and filled with this ash napkin stuff. It was very fragile and difficult to work with — if you blew on it too hard, it would crumble.”

Sarah awakens from her horrifying dream determined to prevent it from ever becoming a reality. Intent on murder, she makes her way to the home of Miles Dyson, whose research will ultimately lead to the creation of the Skynet computer defense system. Once there, however, her resolve crumbles and she finds that, even in the face of such dire consequences, she cannot complete the cold-blooded act. John and the *Terminator* — who have guessed her intentions — arrive at the house and, with Sarah, relate the ominous future history of Skynet and Judgment Day to Dyson. To prove their story, the *Terminator* reveals the robotic arm beneath his cyborg skin. “Greg Figiel sculpted a false arm which blended onto Arnold’s shoulder,” said Shane Mahan. “It was a false shoulder, bicep, forearm and hand based on measurements from Arnold’s lifecast. It was actually sculpted over the mechanical arm — which was built by Charles Lutkus — so that when we eventually put the arm inside the finished foam rubber piece it would be a perfect fit.”

The mechanical arm — which was also used for shots with the endoskeletons in the future war sequence — incorporated a realistically articulated hand. “The original *Terminator* had an articulated hand that opened and closed its fingers,” recalled Winston, “but I had always wanted to take that technology further — because fingers don’t just open and close at one joint. The joints move independently and they can move backwards and they can make an S-shape. When you roll in your fingers, each knuckle is doing something independently. So I wanted to develop this double-jointed, articulated hand. Much of it is self-serving because the audience may not even notice the difference. But I think that attention to detail is what makes people believe what they are seeing.”

In the scene, the *Terminator* slices his arm open to reveal the endoskeletal arm within. “We predressed the cuts,” said Mahan. “On the inside they were painted and dressed like flesh. We lubricated the steel hand, put blood on it, then slipped the whole rubber hand and arm on like a

glove. Arnold held the arm up against himself and cut it with a knife, popping it open as he went up the prescored cut. Then he put the knife down and grabbed the edge of the skin back towards the elbow; and with one big violent rip, he snapped it off. Of course, we had to be prepared to put it all back on again for subsequent takes, so it was designed to be reused. Karen Mason stitched a very tight spandex understructure to the foam rubber which was put over the core of the robotics when the foam was run — so it was impregnated right into the foam. That made the skin very durable. Without it, eighth-inch foam would have just torn right in half on the first take. But we were able to use this same skin each time. We washed the blood off and put the skin back on — all in just a few minutes.”

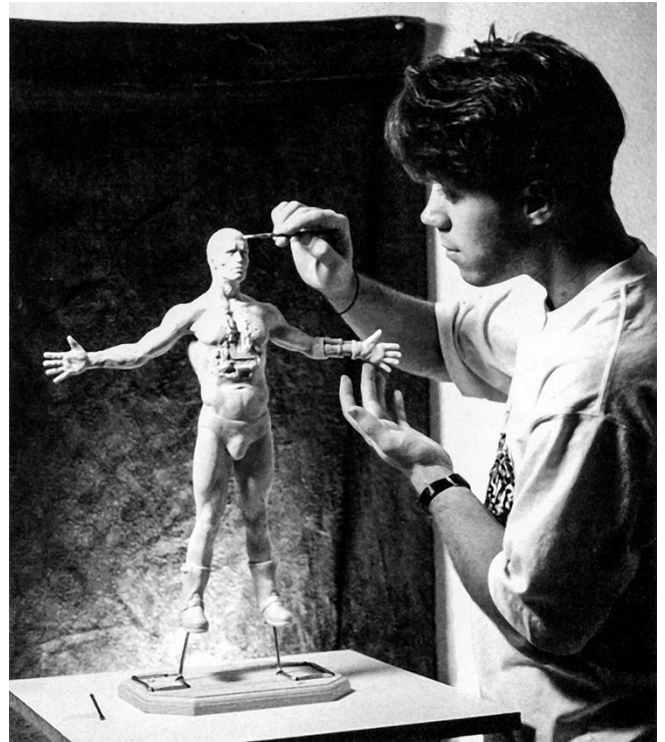


The multi-vehicle chase reaches its climax when the Terminator leaps onto the hood of a liquid nitrogen truck being driven by the T-1000 and forces it to jackknife and overturn into a steel mill. Key elements of the sequence featured a model truck — thirteen feet long — which was photographed on a miniature steel mill exterior constructed at Fantasy II.

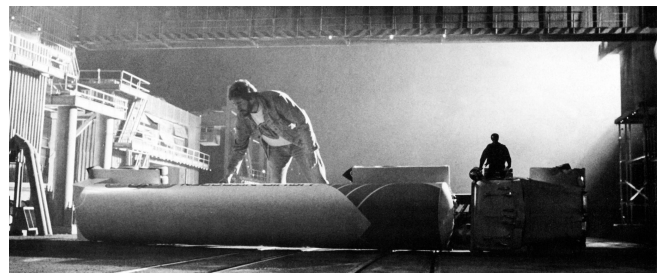
Convinced of his unwitting contribution to the future horror, Dyson agrees to go to Cyberdyne with the trio and destroy every trace of his research. While there, the *Terminator* takes on a heavily armed SWAT team which has been deployed to stop them. Cameron had specifically wanted shots of the *Terminator* taking bullet hits in the face — shots which obviously could not be achieved with Schwarzenegger. To realize the action sequence, Stan Winston's organization created a head-to-hips *Terminator* puppet that could be intercut with live-action footage of Schwarzenegger. "We worked with the special effects guys," said Rosengrant, "and rigged the whole side of the puppet's head with more than thirty squibs. We had done a body cast of Arnold, head to toe, and from that we pulled a fiberglass form and made a silicone mold. We used that mold for the body of the Cyberdyne puppet and for the *Terminator* dummies we had to make for stunt use."

Landon's mechanical effects team fitted the puppet with radio-controlled facial articulations. In addition, to better simulate a human gait, the puppet was equipped with a flexible steel spine built by Brock Winkless. "Spine movement was something I had always felt was missing from our puppets," admitted Winston. "So, for this film, we gave the walking *Terminator* puppet and the endoskeletons organic spine movement, which we didn't have in the first film."

The Cyberdyne puppet was mounted on an elaborate walking rig that was an advanced version of the one first developed during *The Terminator* for the endoskeleton. "For the first film," Winston recalled, "we developed a rig that was based on Jim Henson's puppeteering technique. It was basically worn on the shoulders of the operator so that his walking gait would translate to the puppet mounted above. We took that another step with the rig we developed for my film, *A Gnome Named Gnorm*. Because that character was only three feet tall, we had to come up with a new rig that had a boom arm and could be carried in front of the operator — it would have been too tall if it had been mounted on his shoulders. Then we came to *Terminator 2* and developed the rig further by making it more lightweight and using Steadicam harnesses."



A puppet replica of Arnold Schwarzenegger — sculpted by Dan Platt — was equipped with radio control servo motors for use during the truck slide and then later converted for stop-motion duty when the *Terminator* is thrown from the rig upon impact.



Joe Viskocil — who provided smoke and spark effects for the sliding tanker truck — ignites smoke fuses just prior to a shot. The principal action was achieved via cables concealed in the miniature railroad track channels.

“We bought vests for the Steadicam 3A,” elaborated Landon, “which is a very nice, contoured vest. Then we added our own aluminum mounting points to the small of the back and the stomach area. Moving straight away from the operator’s body was a one-inch-by-three-inch aluminum boom that was adjustable in length. At the end of the boom, reaching down to the ground, was a heavy-duty swivel wheel, which was basically an oversized caster. Sitting on that point was the puppet. In between the puppet and the boom arm — right at the tailbone of the puppet — was a bobbing device that made the puppet rise and lower as he walked.”

The walking rig was worn and operated by Shane Mahan. “My job was to provide the basic walking motion for the puppet. The rig was locked to my body with the harness so that it took most of its motion off of my hips. When I moved my body up and down in a walk, the puppet took on that movement. I also controlled the arm motion with two rods that were attached to the elbows. They were very thin and painted black and bent on an angle so they couldn’t be seen in the shot. The boom arm could be positioned anywhere — to my side, at a forty-five-degree angle in front of me, or directly in front of me. It had a rotational point at the hips that could be locked off wherever we needed it for a specific shot.” Though Mahan provided the gross walking movement and the swinging of the arms, three additional operators with cable controls supplied the other articulations. “There is quite a lot that goes into a human walk. The three operators controlled the hip and shoulder motion, the up/down motion, and also the neck and head motion. Their cables ran about twelve to fifteen feet behind me, and they could either walk behind or swing around ahead of me and walk backwards. It took two to three steps to get the whole locomotion of the thing going. But after a couple of steps, we’d get into a natural rhythm.” To fine-tune their performance, the puppeteers had videotaped Schwarzenegger’s walk and studied it. “We had it down pretty well by the time we got to shooting it. Also, Arnold helped by watching how the puppet walked and then copying that walking motion during the live-action. Arnold is very cooperative in that way. He did the same thing with all of the puppet heads — if the head made a funny, specific kind of move, he would mimic that move to help insure that the puppets cut in well with the live-action photography.”

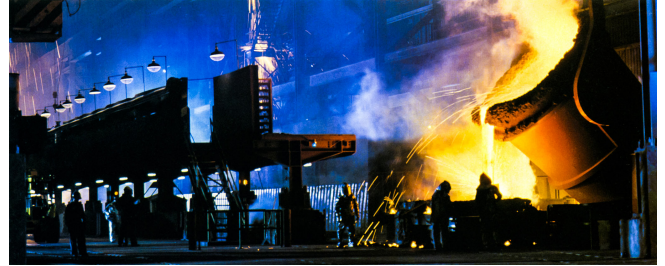
Surviving the Cyberdyne firefight, Sarah, John and the *Terminator* escape, leaving Dyson to set off the explosion that will destroy the high-tech facility and its lethal research. The explosion was a major logistical feat which required hours of rigging and hundreds of gallons of gasoline to produce a gigantic fireball that would look devastating on film while inflicting as little actual damage to the building as possible.

The chase continues when the T-1000 — who has driven a motorcycle to the second story of the building in search of his targets — spots the threesome escaping in a SWAT van appropriated by the *Terminator*. As a police helicopter hovers outside, the T-1000 drives the motorcycle out the window, grabbing onto the helicopter as the bike strikes the chopper and falls to the ground. The stunt was achieved by harnessing the rider with bungee cord to insure that at a designated point he would be yanked safely off the motorcycle and onto a pile of cardboard boxes. The stunt and the hovering helicopter were shot as two separate plates and then split-screened together by Pacific Title. “One pass was of the helicopter flying near the building,” Van Ling explained. “The second pass was a shot of stuntman Bobby Brown riding the motorcycle out the window. We had tried to shoot it as a motion control shot — we had a field recorder out there on location so we could do a pan — but

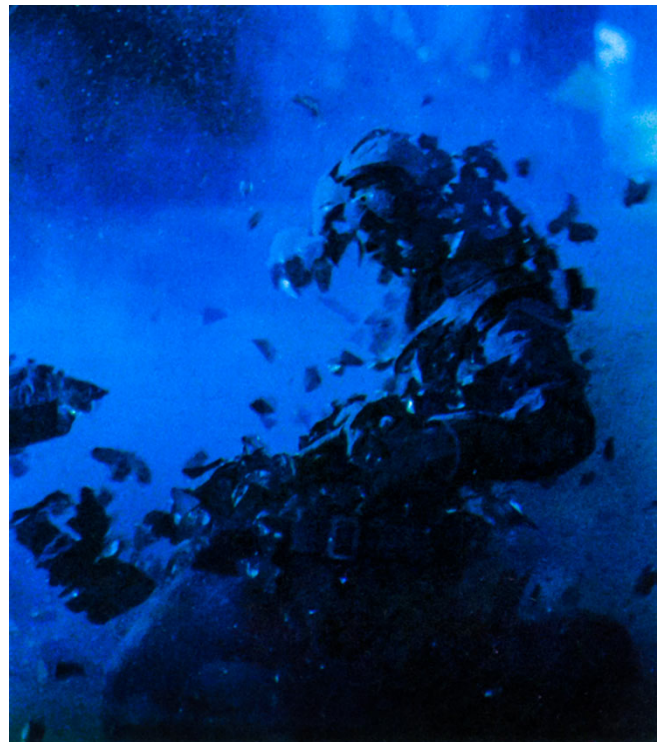
when we went to shoot the stunt, the motion control head on the camera couldn't move fast enough to follow the action. So we had to use the locked-off versions that we shot as insurance coverage — which worked out fine." Still visible in the split-screen composite, however, was the safety cable attached to the stuntman. "Pac Title had to go in and roto out the cable — which was quite a chore because it was there in the middle of a cloud of broken glass and debris. They did the removal very meticulously so that none of that debris was disturbed."

Clinging to the hovering helicopter, the T-1000 changes to his liquid metal form and literally pours himself into the cockpit through a hole in the canopy. "We used an improved version of the pseudopod software from *The Abyss* for getting the shape of the object," said Jay Riddle. "The nature of the T-1000 material is very different from water, so Joe Pasquale and Rich Cohen had to spend some time developing the animation to make it seem very heavy and dense so that it would flow in a convincing way. In our first tests, it looked like the creature just hopped into the helicopter seat — it was in the shape of a tin can and then expanded into a human form. We realized, however, that the volume of this mass had to remain consistent as it poured in — it couldn't be small and then suddenly get big. These shots were also the first ones we did that had reflections of the surrounding environment. I photographed the inside of the helicopter from several different angles so that we could piece those reflections together."

Once inside the cockpit, the T-1000 becomes the Number Four liquid metal cop and orders the pilot to get out. Animated by Jay Riddle, it was the only line of dialogue required of the computer modeled chrome man. To correctly model the speaking facial expressions, the computer team had laser scanned Robert Patrick at Cyberware. "We had Robert pose for each part of the line," said Mark Dippe. "He'd say 'Ge-' and we'd have him hold that pose for fifteen seconds while it was digitized. Then he'd say '-t' and we'd have him hold that. It was very hard to get the heads to line up, because as he spoke each syllable or made each sound, his face would obviously change. So we took two slide projectors and we projected grids on him and put little black dots of



For the grand finale, production designer Joseph Nemec III orchestrated the clean-up and renovation of a long-dormant steel mill. Incorporated into the setting were two replicas of the giant ladles used to hold and pour hot metal. The molten steel itself was simulated with high-intensity backlighting and steam. Underwater arc welders were used to produce spark effects.



When the overturned truck crashes into the mill, liquid nitrogen pours out of its ruptured tank and the liquid metal T-1000 is frozen solid. The Terminator opens fire and his adversary shatters into hundreds of tiny fragments. A dummy replica of Robert Patrick was cast from a fragile resin, then painted and filled with vacuum metalized urethane shards. The figure was rigged with explosive charges and hit from above with an air

makeup on his face where the grid was. As he held each pose, we'd digitize him and then let him rest. Then, when we were ready to do the next part of the sentence, we'd line him up with those grid lines to make sure his head was in the same position." Even with careful alignment, the rendered shots were plagued by jittery movement of the character's sunglasses. "Michael Natkin developed a technique whereby only the bottom part of the face was animated," said Riddle. "The entire upper part — which had the glasses — remained stationary."

~~cannon blast so the pieces would drop straight to the ground~~
~~The radio-controlled Terminator clings to the jackknifed truck cab as the miniature big rig begins its roll.~~

As the terrified pilot leaps from the cockpit, the T-1000 — now at the controls — continues his dauntless pursuit. While his targets race down the freeway in the SWAT van, the T-1000 follows close behind, exchanging automatic weapons fire with Sarah. Though much of the chase was shot live — with stunt pilots Chuck and Mike Tamburro at the controls — closeups of Robert Patrick were achieved with a mockup helicopter suspended from a crane arm attached to a moving flatbed truck. The same rig was employed to crash the pyro-laden mockup into the rear of the SWAT van later in the sequence.

Undaunted by the crash, the T-1000 commandeers a liquid nitrogen tanker truck and continues his pursuit of Sarah, John and the *Terminator* who have fled the scene in a small pickup. The high-speed chase comes to a harrowing conclusion as the *Terminator* leaps from the pickup to the tanker, shoots out the window and yanks the steering wheel, forcing the giant rig to jackknife and flip over. As storyboarded, the tanker truck was to crash through the gates of a steel plant, jackknife violently, then roll onto its side and slide into the mill. Though Cameron had intended the sliding aspect to be achieved in miniature by Fantasy II, he attempted the jackknife roll as a live-action stunt. When the full-size tanker failed to roll in its predetermined spot, only a few moments of the resulting footage were deemed usable and Fantasy II picked up the rollover as well.

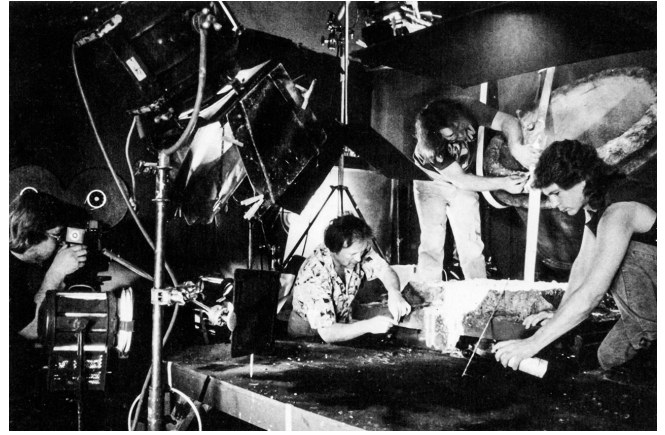
After taking measurements and photographs of the actual site, visual consultant Jerry Pojawa headed up a task force to reconstruct the entrance area and exterior in quarter-scale. "The steel mill miniature set was about sixty feet long by twenty feet wide and extended up about ten feet," recalled Mike Joyce. "It was also built two feet off the ground so that we could go underneath and rig things. The steel mill entryway where the tanker truck had to crash had a steel substructure to make it solid. The rest of the set was primarily vacuform plastic — hundreds of pieces. There was also a lot of quick-and-dirty construction — railings made with dowel and windows that were acetate. It had to be a large and fairly detailed miniature because some of our shots showed the whole thing, all the way up to the roofline."

A quarter-scale tanker truck — thirteen feet long — was built for the sequence, primarily by Monty and Dwight Schook. "When we went into production," Joyce continued, "the live-action truck had already been picked out, so we photographed it and measured it. Monty carved the body out of foam and it was then vacuformed out of eighth-inch styrene. The cab had full working suspension and steering and lights — as well as a full interior which John Eaves detailed." Wheels for the truck were custom made. "We photographed the tread of the real tires, then had that photograph blown up to the right size for our miniature tires. From that we were able to acid-etch a piece of steel and make our mold. We then cast that tread in rubber and wrapped it around and made a mold of the whole tire so that we could cast up as many of them as we wanted."

Though only one carriage was needed, four truck cabs were fabricated — one for the rollover and sliding shot, and three with lead tops for the scenes where it was to impact with the steel mill doorway. Two tank sections were also constructed — each serving different functions. “The tanks were made from PVC tubes that were capped on both ends,” said Joyce. “The first one was rigged to tip over with hydraulics. The second was a thicker-walled tube that we cut in half lengthwise. A huge hinge was made for it so that it could be split open when it crashed into the wall.” Inside the model tank was a canister which held a mixture of liquid nitrogen and alcohol. “There were pneumatic actuators that would open the tank and roll the canister over so that the liquid nitrogen and alcohol would dump out. It was all breakaway, with lead at the top and bottom for weight, and it was rigged so that we could do as many takes of the truck splitting open as we had to — it was just a matter of resetting the hydraulics and refilling the dump tanks.”

Railroad tracks patterned after those at the actual steel mill site were a convenient element of the set. “We were able to use those tracks to hide a cable and dolly system which we attached to the truck,” said Gene Warren. “That system was used to slide the rig on its side. Then, to get all of the specific actions — like the jackknife or the tipping over — we had different cables going off to separate operators. Each shot had to be rigged individually to make the truck do what we wanted it to do. The most difficult thing was that it had to end up in the exact same position as the live-action which was already shot. The way that was staged was not the way a truck would actually behave — but we had to make it end up that way and we had to make it look natural.” Smoke produced with burning cannon fuses was added to shots of the tanker truck sliding on its side.

As the overturned rig screeches across the asphalt toward the steel mill, the *Terminator* climbs onto the cab and rides the sliding juggernaut as if atop a surfboard — a stunt performed successfully during the live-action shoot. Corresponding miniature shots employed a fourteen-inch-tall *Terminator* puppet sculpted by Dan Platt. The steel-armatured figure was used first as a radio-controlled puppet for shots of the *Terminator* pulling himself up as the truck rolled over. Then, after



Since the lighting effects used to simulate molten steel on the live-action set were unable to depict a convincing spill, several closeup shots were accomplished at 4-Ward Productions using miniatures. White paint was poured into a quarter-scale tundish and allowed to overflow. The whitened areas of the frame were then optically extracted and gelled and printed back into the scene at sufficient intensity to make the fluid appear luminous. Dennis Skotak takes a light reading while Robert Skotak, Joel Steiner and Ricc Ruskuski attend to final details.



Already bearing facial wounds from the shootout at Cyberdyne, the Terminator is further defaced after the truck crash. Three stages of prosthetic makeup were created by the Stan Winston team — each revealing further injury and greater exposure of the cyborg's endoskeleton.

removal of its radio control servos, the figure was refitted as a standard animation puppet for frontlight/backlight go-motion shots animated by Pete Kleinow.

The go-motion shots were of the *Terminator* leaping off the truck, hitting the ground and rolling toward camera. The puppet was mounted on wires and animated against a rear-screen process plate of the miniature tanker truck. "There was no foreground miniature at all," Kleinow stated. "It would have been very difficult to build a foreground piece that matched up with the background plate, since the background extended right up to the lens." Though the puppet was suspended in midair, a jump was animated and lined up to the process projection to appear as if the figure were leaping from the truck to the ground. "The puppet had to spin completely overhead, so that needed to be done with a hanging system. We had a track with a north-south and up-down move, and a hanging rig which I designed that could be tipped and trimmed. The puppet was go-motioned forward and then landed on the ground — which I lined up to the rear process screen through the camera. Of course, the puppet actually just landed in space, so I had to animate the body effect of him landing on the ground. As he came down, we brought in a shadow to place him more believably in the scene. We produced that shadow with a piece of neutral density material that was go-motioned on another track between the projector and the screen." Two months — and twenty-five takes — were required before the shot was achieved to Cameron's satisfaction.

The crash into the steel mill marks the beginning of the most effects-intensive sequence in the film. Just finding a suitable location had been a major feat. When an abandoned steel mill was located in Fontana and secured for the production, Joe Nemec and his art department moved in and commenced major renovation. In addition to platforms, additional stairways and a giant conveyor constructed out of wood, the production built two wood-and-plaster replicas of the giant ladles used to hold and pour molten steel.

From the beginning, the intention had been to achieve the molten steel effects primarily with light — although at first there were only vague notions as to how that might be realized on a large scale. Extending from the lip of each ladle was a fiberglass 'pour' designed to simulate molten steel sluicing into turn-dish cars. "Jim was very specific," said lighting consultant Richard Mula. "He wanted the pour itself to be a brilliant white hot — but he also wanted it to cast an orange-gold kind of light onto the set and the people around it. I contacted a company that I had worked with to acquire the special lights we used on the models in *The Abyss* and I was able to get prototype T-3 tungsten lights. They were half an inch in diameter and twelve inches long, and each lamp was fifteen hundred watts. We put two banks of eighteen lamps in the middle of each fiberglass pour unit, staggered in such a way that from a distance they seemed to form a solid line of filament. Those gave us the white-hot light that we needed." The central T-3 units were augmented with fluorescent lamps mounted on either side of the pour. "I went with fluorescents because we needed so many lamps and it would have been impossible to use that many incandescents — the heat would have been tremendous. The fluorescents were flicker-free, with a light output that was two or three stops less than what the high-output tungstens produced. So the pour had all of these fluorescents on the sides for the cooler orange light, and then the tungstens down the middle for the white-hot effect." Even with the fluorescents, heat generated by the megawatt lighting setup mandated that refrigerated air be pumped into the pour every time the lamps were turned on. "We could leave the fluorescents on for a few minutes at a time, but the tungsten 'high beams' were on

only when they were actually shooting. In one instance, the air conditioning wasn't working — which nobody realized — and the inside of the fiberglass pour caught fire. It took quite a while to get the fire out and the pour had to be rebuilt.”

Adjacent to one of the ladles was the ‘death pit’ — a vat of molten steel that would eventually consume both terminators. In reality, it was a clear acrylic tub filled with water and translucent mineral oil. “Gary Tandrow — the first unit lighting gaffer — had put approximately thirty-nine lights around the outside of the death pit where the liquid was only a foot or so deep. Then in the center — where it was about three feet deep to accommodate the actors — we put a circle of underwater lights.” Underwater HMIs — like those Mula had developed for *The Abyss* — were tested for the death pit lighting, but because HMIs emit a blue-white light and would have required heavy gelling to produce the orange glow that Cameron wanted, Mula decided to augment them with tungstens. “Jim felt that the tungstens were closer to the quality of the light source that he wanted. We used about thirty Par 64s and then another twenty of the smaller Par 36s to fill in spots.”

Mula was also responsible for devising the liquid mixture that — with appropriate backlighting — would simulate the molten steel. Initially, the plan had been to use methocel — but experimentation revealed that the slimy substance cut virtually all of the light. “We tried other things like milky water and milk with orange dye in it, but those also failed. Finally I got the idea of using mineral oil and water. I reasoned that we could color the oil — which would float on the surface — and not worry about the clear water underneath obscuring the light. All we had to do was come up with the right ratio of water and oil so that when the actors were floundering around in the pit, their legs and bodies underneath the oil layer would not be visible — obviously, if they were submerged in *real* molten steel, they would not *have* legs and bodies. After trying a few substances, I settled on mixing powdered sugar into the oil to cloud it up. At first, I mixed it all together with a big paddle in fifty-five-gallon drums. But because there were times when I needed as much as four hundred gallons of it — it took a hundred gallons per inch to cover the pit — that approach became very tedious. Finally I discovered that I could use air to mix it. I found some rubber hose in a junk pile and plugged the end and drilled holes in it so the air could get out. Then I hooked it up and stuffed it into the drum and turned on the air — and the mixture came out perfectly. The air bubbles would stay suspended in the oil for four or five hours and they actually reflected the light very nicely. Eventually, I was able to omit the powdered sugar completely — the air bubbles alone were the perfect solution.”

While the intense lighting built into the on-set steel pours was more than adequate to suggest molten steel from a distance, a few closer shots were needed to sell the notion that the material was actually fluid — especially in the scenes where the giant ladle overflows onto the floor after the tanker crash. Since 4-Ward Productions had been contracted prior to principal photography to develop in miniature the lighting technique that would later be applied full-scale to simulate molten metal on the set, they were also contracted to produce the closeup spill material. “The preproduction prototype we created,” said Bob Skotak, “allowed us to pinpoint how the molten steel effect could be achieved live-action without use of opticals. For these initial tests, we built a fifth-scale generic steel mill set and shot it all in one pass at twenty-four frames per second, utilizing physical gags — smoke, methocel, neon tubes — to simulate the look of a vat of hot fluid metal. This was exactly the way the live-action crew would have to film it. But at the same time, since it was

not practical to spill massive, full-size quantities of fluid on the actual location, we were asked to duplicate that exact look for several anticipated non-full-size closeups — this time using an actual liquid spilling out of the tundish to form a no-doubt-about-it hot metal puddle. This sort of effect could not be done using the live-action gag, because once you got close to it, it was clearly nothing but light. So we came up with the idea of pouring white paint from the ladle into the tundish and then pulling a matte off that and optically printing in that information up to a level that made it appear luminous, rather than just like flat white paint. That way, we were now dealing with liquid light that we could enhance with graded mattes and diffusion in order to create the orange glow we needed.”

Although the paint spills were shot on a quarter-scale replica of the steel mill set, other elements were shot separately — full-size — and composited optically into the shots. “We built a full-size mockup of the tundish in black for shooting the more kinetic elements of fire, sparks and smoke, using a lineup clip of the miniature in the finder to get the correct perspective. There was a lot of going back and forth to fine-tune the match to live-action, but it all came together very nicely. Our editor Peter Miller and Bob Costa worked closely with Dave Hewitt to produce the final composites. We did three shots in all, but one of them was dropped to shorten the sequence.”

It is into this orange hell of sparks, smoke and white-hot molten steel that the tanker truck crashes, spilling its load of liquid nitrogen. As the T-1000 emerges from the cab and comes in contact with the freezing liquid, his fluid metal composition begins to solidify. Continuing to struggle forward, the T-1000 breaks apart at his legs and wrist, leaving icelike splintered stumps before coming to a complete and frozen stop. The sequence was a particularly taxing one for the Stan Winston crew. Shane Mahan — together with Jeff Dawn, Steve LaPorte and Ed French — began by experimenting with ways to achieve the basic frosted look for the character. “Jim wanted a frost effect that — without using animation — would look like it was taking over Robert Patrick’s body relatively quickly and from the ground up,” said Mahan. “Fortunately, this was around Christmastime and Jeff found a prismatic tinsel — like snow tinsel — which he chopped up into little confetti-like chips. Then we took an



Separated from her companions, Sarah is cornered deep within the mill by the T-1000. Injured and barely able to walk, she nonetheless manages to fire a close-range shotgun blast at her assailant that punches a hole completely through his head. The initial phase of the effect was accomplished with a Stan Winston puppet operated live on the set While puppeteers provided cable and radio control articulations, Robert Patrick twisted himself into position to use his own arm in the shot. The closure of the wound was effected in two computer graphics cuts.



After recovering, the T-1000 retaliates by jamming a spiked finger through Sarah’s shoulder. The finger was transformed into a chrome spike via computer animation, but subsequent shots employed prosthetic finger

aerosol adhesive and sprayed a few inches of it around Robert's feet and stuck this tinsel on him and then sprayed that with fake snow. Jim would shoot it and then we would add a little more, gradually going up his body and filming it a little bit at a time. Finally, he was totally covered with this stuff — his face and everything. The whole effect was done over the course of five different nights."

extensions and a shoulder cup worn by Linda Hamilton to suggest that the spike had passed completely through her.

The next part of the sequence, in which the T-1000's frozen legs snap off at the knees, required the assistance of double amputee Larry Johnson. "Larry is an amazing guy who walks on prosthetic legs," said Mahan. "His right leg is missing from his mid-thigh down; his left leg is missing from about mid-shin down. We took the prosthetic devices that he wears — which are like aluminum struts with heavy knee joints and fake feet with spring ankles — and fit them inside a pair of urethane boots that we made. We cut into both the prosthetics and the boots, segmenting them into puzzle pieces. Richard Landon then built an elaborate cable device which ran through all the pieces and cinched the whole thing together. Larry Johnson put these fake boots on and took a step — and as he did that, the cable device was actuated so that the boot came apart and broke into all of these shards. Larry then came down on his residual limb. Then he took another step and the same thing happened on the other leg."

In the following shot, the T-1000 breaks his fall, coming down on his right hand. When he attempts to rise, his frozen arm snaps off at the wrist. Patrick was fitted with a jacket that had a false arm attached to it. "His actual arm was behind his back and the false arm was cable-controlled. We had a false hand placed on the floor and that false arm would meet the false hand, with Robert leaning forward and putting his weight into it so that the seam between the arm and the hand would be tight. The hand had been segmented and then cabled together, just like the boot. On cue, Robert would pull away and the hand would fall into shards on the ground. At that point, he stops and looks at his broken-off arm and then freezes to a complete stop."

Taking advantage of his adversary's immobility, the *Terminator* opens fire on the frozen T-1000, causing him to shatter into hundreds of chrome shards. Robert Patrick was first photographed in a frozen pose — his real legs extending through a false floor to give the illusion that he was standing on broken stumps. Then he was replaced with a dummy. "We did a sculpture of Robert in his final pose," said Mahan. "Then we made a silicone mold of that and ran a gel-coat resin copy — very thin — which we painted to look like his cop uniform and helmet. It was a hollow sculpture that we filled with shiny metal flakes and '281' shards that we had vacuum metalized. TC-281 is a self-skinning urethane foam. So we just filled the body with those chromed shards and glued the whole thing together. Then the physical effects guys wrapped it with primer cord in various spots to blow it up. Jim wanted him to shatter like broken glass rather than have the pieces fly all over the place. Three air mortar cannons were placed above the sculpture so that when it blew, all the pieces would fall straight to the ground."

For a moment, it looks as if the T-1000 has been beaten. But as the frozen polyalloy shards come into contact with the heat generated by the overflowing molten steel, the killing machine begins to reform once again. Though the final transformation from liquid metal pool to the live-action T-1000 was a computer graphics shot, the initial scenes of the shards melting into gleaming puddles and then moving towards each other were miniature shots which the Skotaks achieved using globules

of mercury. Because of its extreme toxicity, mercury was not the substance of first choice, but other materials such as lead solder, wax and silver paint had failed to create the desired effect. “We found that mercury is very, very hard to control,” Dennis Skotak noted. “It has a tendency to move at the slightest provocation. The *slightest* movement, even your own breath, could send the little pools of mercury sliding across to the other side of the set. And, of course, we had to wear protection — gloves, dose badges, respirators and everything.”

“It was like trying to set a bunch of ants down and getting them to stay put,” elaborated Bob Skotak, who was the self-appointed mercury wrangler. “After about two days of that, I was seeing red. The stuff is *alive* — it is living matter and it will do anything possible to drive you crazy. Finally, out of sheer desperation, I grabbed a can of spray adhesive and sprayed the mercury down — and it worked! I found that by just giving it a light dose of adhesive, the mercury would stay put. I had to be careful with it though. If I used too much, the mercury would not move at all.”

The first shots in the sequence show the shattered T-1000 shards melting down into liquid metal form. “Our original idea was to actually freeze mercury — which we did by splintering out holes in dry ice and pouring it in — but when mercury was frozen, it became so cold that frost formed on the surface and it turned white. We also experimented with lead solder melted down and poured into clay molds; but we found that it wasn’t possible to melt them fast enough or in an attractive way — they would oxidize and blacken. Finally we ordered some serabin — which is a leadlike metal used for ballast on model railroad cars. Serabin melts down in boiling water; and when it is molded and buffed up, it really looks like chrome. So we made our pieces out of this stuff and then placed them on a set with a Coleman stove underneath and propane torches overhead and shot them undercranked as they melted.”

Having mastered the movement of the mercury for isolated closeups, Skotak shot the master view of dozens of mercury beads flowing together to form a single pool. This was done on a three-foot-long tabletop set and shot at forty-two frames per second. “The table had a small tumbuckle under it that let us crank down the center area, which helped make the pools flow inward towards the center. It had to be very subtly done. We also used air lines to blow the mercury in the direction we wanted it to go. This was all shot in Vistavision and split-screened into live-action elements of the full-sized tundish so that this pool appeared to be forming on the floor of the mill as the heat intensity melted the T-1000 shards.”

Though only a few shots in the film bear their signature, *Terminator 2* proved to be one of the most difficult and demanding projects the Skotaks had ever encountered. “We were using materials throughout that had very random qualities,” Bob Skotak concluded, “things like steam and fire and breakaways and mercury — even air blasts have their own dynamics. Everything was intangible and nearly uncontrollable. There was always a certain amount of serendipity involved. To get our shots, we had to try to isolate and control that randomness so we could predict what was going to happen.”



After his reduction to a pile of icy fragments, the T-1000 returns to his mobile form when molten steel overflowing onto the floor nearby melts the frozen shards into fluid blobs. ILM produced a computer graphics shot with a dramatic camera move to show the T-1000 transforming from a pool of liquid metal into his preliminary humanoid shape.



Computer animation was also employed during a scene in which the Terminator punches the T-1000 so hard that his fist passes completely through the liquid metal head.

The final transformation from liquid metal pool to the liquid metal man required three computer graphics shots supervised by Jay Riddle. “In the first shot, the *Terminator* and John are standing near the polyalloy pool as the T-1000 starts to form. In the pool itself you can see their reflections. We used a simple technique, taking the background plate and putting it on a reflection plane, then placing it right behind the puddle we were animating. That image would then reflect into the puddle as we rendered the surface.” The subsequent shot — animated by Annabella Serra — is an overhead view of the polyalloy continuing to form into a human shape. “The shot starts high above and then booms down and around to a front view and a closeup of the T-1000. Originally it was just going to be a lock-off, but I suggested the camera move to give the shot some emphasis. We ended up not doing any motion control on that shot at all — we just used a camera on the end of a crane. There was a C-stand mounted on a regular camera dolly and the dolly grip raised the C-stand head through the shot to represent the T-1000 rising up. The camera operator kept the C-stand in frame as the camera boomed around. So all we had to work from on that shot was the C-stand in this vast space. Rich Cohen matched that camera move and Joe Pasquale worked on the transformation from a blob shape into the Number Four. We had to keep working back and forth and running tests until we finally got it. Alex Seiden came up with another version of the polyalloy shader that allowed some of the shadows creeping along the floor in the early stages of the shot to waft over the polyalloy man, thereby placing him on the ground just a little bit more.”

Once the T-1000 regains his human shape, his final battle with the *Terminator* begins in earnest. As scripted, the T-1000 was to show signs of malfunctioning during this sequence. The first indication that his capabilities had been compromised was to be a shot of his hand touching a railing marked with OSHA safety tape. His hand



To draw John out of hiding, the T-1000 transforms into the shape of his mother and calls out to him. When he later reverts to his cop form, a computerized morfining technique was employed to digitally transform the Linda Hamilton, T-1000 to the Robert Patrick T-1000 in a single uninterrupted shot.



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and arm were to take on the OSHA striping and, as he tried to pull away, momentarily remain stuck to the railing — a Stan Winston gag achieved with a flexible urethane arm painted with yellow-and-black stripes. After pulling it free from the railing, the T-1000 examines his malfunctioning arm and flicks it, making the stripes disappear — a digitally composited bluescreen jump-cut provided by ILM. ILM also produced a subsequent shot of the T-1000's feet taking on the diamond pattern of the steel mill floor. Boots walking through the frame were shot motion control, then matched to computer modeled boots which had the diamond pattern on them. With each step onto the grating, the diamond patterned boot would be animated onto the live-action boot in a wipe. As the boot stepped off the flooring, the pattern would disappear in another wipe.

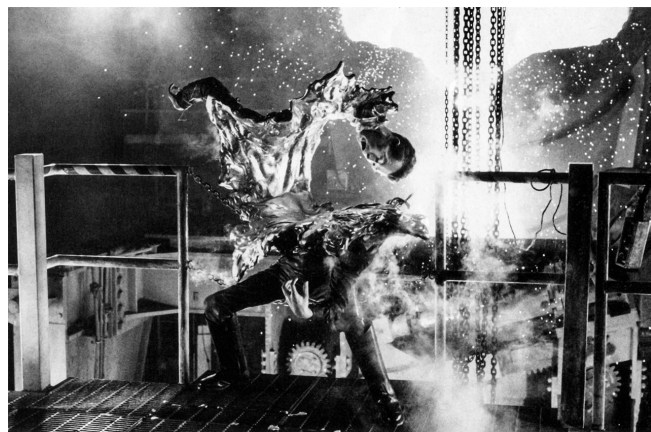
Another sign of the T-1000's impaired capabilities was to be a series of 'glitches' — chrome bars moving across his body that looked somewhat similar to a malfunctioning vertical hold on a television screen. "It was a metallic vertical wipe that went up his body," said Jay Riddle. "We match-modeled Robert's body and then Joe Pasquale matched his position in space. So there was a computer graphics chrome figure over the live-action Robert Patrick. Then we selectively pulled only one piece out of that with a kind of matte that we created which was the shape of the wipe that went around him as he glitched. We just pulled that chrome part out, frame by frame, and moved it up his body." Ultimately, all of the malfunctioning T-1000 shots were cut — except for one brief instance after a skirmish with the *Terminator*. "It was a matter of pacing," Cameron observed. "The chase would be going full-steam — and then, suddenly, the T-1000 would stop and look at his hand. Then the chase would continue — and a moment later he would stop again while his feet transformed. Those shots were absolutely amazing — the boot shot, in particular, was incredibly surreal — but ultimately, you have to serve the film."

In hand-to-hand combat with his nemesis, the *Terminator* lands a punch in the T-1000's face, but his fist merely passes through the liquid metal to the other side. In the following shot, the T-1000 forms

was employed to digitally transform the Linda Hamilton, T-1000 to the Robert Patrick T-1000 in a single uninterrupted shot. When he later reverts to his cop form, a computerized morphing technique was employed to digitally transform the Linda Hamilton, T-1000 to the Robert Patrick T-1000 in a single uninterrupted shot.



The Winston makeup team was responsible for rigging the many bullet hits endured without suffering by the T-1000. Liquid metal splashes were cast out of soft foam and vacumetalized to look like chrome. They were then folded into a spring-loaded mechanism that would cause them to pop open instantly when cued via radio control. Art department coordinator John Rosengrant and mechanical coordinator Richard Landon rig Robert Patrick's prescored shirt with bullet hits for the climactic shootout in the steel mill.



hands out of the gaping hole and proceeds to reengage the *Terminator*. “Those were the most challenging shots my team had to deal with,” said Riddle, “because there was direct human interaction with the CG elements. As the *Terminator*’s fist hit the T-1000’s face, we distorted the image so that it looked like the face was caving in. Then we

A grenade fired into the T-1000’s stomach causes a major rearrangement of his liquid metal components. A puppet constructed in a splayed-open configuration was mounted on a gimbal and made to teeter about from below via rods extending up into its legs. Radio control and cable mechanisms provided additional articulations.

animated the T-1000’s head to stretch as the *Terminator*’s fist exploded out the back of it. We had to animate the head shape that was surrounding the fist to try and show the resistance of this dense metal holding onto him. It was a lot of work to match up that blob of metal with his hand as he was twisting around.” To make the fight look convincing, the computer model’s actions had to correspond logically to Schwarzenegger’s movements in the live-action plate. “It was hard just to set up the plate photography and make it look like Arnold was being thrown around by the T-1000. Joe Pasquale had to look at the footage and figure out: ‘If Arnold is being thrown this way, what does the guy doing the throwing look like? What position would he be in?’ It was thinking backwards — we had Arnold’s actions in the plate and we had to match the T-1000’s actions to that accordingly.”

Another shot in the sequence included a major morfin’ effect, animated under the supervision of Doug Smythe, for a shot of the T-1000 passing through himself — literally turning inside out as he struck a wall. “John Berton animated that shot and it took about two weeks of his time. When the live-action was shot on the set, there was a video tap set up so that Robert could be positioned without having to physically mark the set. Robert went through the action of running into the wall a number of times. Then, for the next take — which was a shot of the T-1000 stepping away from the wall with his body facing camera — the director tried to line Robert up to his position in the previous take. But the human body doesn’t line up the same way from the front as it does from the back; so when Robert was positioned for the second take, invariably a different part of the background would show. We had to figure out how to bring out the parts of the background that showed in the first take and not in the second, color correcting them so that the blend wouldn’t be too obvious. Then we did a cross-dissolve in the area where they both showed so that it didn’t pop from one to the other.”

As the battle moves to the deeper recesses of the mill, the T-1000 overpowers the *Terminator*, sending him sprawling into a giant conveyor gear where his arm is crushed and mutilated. Winston’s crew fitted Schwarzenegger with a false robotic arm for the sequence. “It was constructed so that it was very fragile right where the tooth of the gear was going to grab it,” noted Shane Mahan. “Arnold had his real arm behind his back. At the wrist of the false arm was a small invisible wire which ran through to the opposite side of the gear. When Arnold fell back, that wire pulled the arm into the gear. I constructed a light mockup of the mechanical arm which was held together with aluminum tape for a later shot in which the *Terminator* grabs a pry bar, shoves it down inside of his arm and snaps it free. The aluminum tape was tearable — almost like aluminum foil — but it looked convincing.” A partial mechanical arm had to be worn by Schwarzenegger for the remainder of the film. Because, logically, the *Terminator* would still be capable of moving the mutilated limb, the appliance had to be marionetted throughout the following sequences. Attached to the false arm

was a thin wire. Mahan would position himself above the actor — on whatever ledge was available — and puppeteer the dangling appendage to give it some semblance of life.

Having temporarily dismissed the *Terminator* — who is struggling to free himself from the gear — the T-1000 goes in search of Sarah and John. Though wounded and cornered, Sarah manages to get off a close range shot at the T-1000. The result is a large — but, of course, temporary — hole in his head. The ‘Donut Head’ effect was achieved using a mechanical head-and-shoulders puppet sculpted by Mike Trcic. “Donut Head was a pretty standard puppet,” Landon said, “except that, since one eye was obliterated by the hole, we had to build a lopsided eye mechanism — which was an interesting challenge. The remaining eye was distorted and warped. It had eye articulation and jaw movement — all radio-controlled — as well as a cable mechanism on the perimeter of the hole to begin the closing action.”

The computer generated closure of Donut Head entailed two cuts — the first, a shot through the hole itself, revealing Sarah Connor in the background; and the second, a shot of the wound healing as seen from the back of the T-1000’s head. A computer generated wound was match-modeled to the hole in the puppet and inserted into live-action footage of Robert Patrick. Then the live-action element of Linda Hamilton — which had been shot without Patrick in the scene — was inserted into the wound opening to create the illusion that Sarah could be seen through the hole in the T-1000’s head. The actual closure was animated and then enhanced with a rippling technique to pucker the area surrounding the hole and place that animation more convincingly into the live-action.

After recovering from the shotgun blast, the T-1000 retaliates, pinning Sarah to a wall by driving a spiked finger through her shoulder. Because of the quickness of the action, the filmmakers opted for a simple arrow-through-the-head-type of gag rather than using yet another puppet. Robert Patrick was fitted with a spiked finger that slid over his hand like a glove. The blunted end of the spike was sharply jammed into Linda Hamilton’s shoulder, which was protected by a fiberglass piece. For the following shot in which it appears that the spike has passed completely through her, Hamilton wore a shoulder cup with welded metal struts on the front and back to hold the protruding ends of the finger spike in place.

Just as the T-1000 goes in for the kill, the *Terminator* — who has freed himself from the crushing gear — advances from behind and literally slices through his adversary’s body with a long steel rod. Originally, Stan Winston had assumed that a complete T-1000 puppet would be necessary for the ‘Cleave Man’ effect. However, when Cameron indicated a willingness to limit himself to a specific camera angle, a much simpler approach was devised. “I started doing drawings of that effect early during the design phase,” recalled Mahan. “Then I did a maquette sculpture which showed a body with one shoulder arched back as far as it could go and the head still facing forward. That created a gap that I could build onto. I built up an arm and shoulder and part of a torso, all the way down to the hip area.” Working from Mahan’s maquette, Chris Swift sculpted a full-sized, foam rubber body section — complete with a chromed splash area on the inside — that could be worn by Patrick. “We also made an entire rubber costume for Robert to wear, because we found that the look of the painted rubber device didn’t mesh well visually with the cloth uniform. Robert stepped into this whole thing like a suit, twisting his body as far back as he could to one side while keeping his head forward. There was a fiberglass plate up against him where the appliance met his body. When it was all pulled together, and from the right angle, it looked like he was standing in a normal posture.

Then Arnold took the skewering device, drove it down the split line, and the appliance would spring open and away from his body.” A subsequent computer graphics shot revealed the Cleave Man torso closing around the steel rod.

The liquid properties of the T-1000 enable him to pull the rod directly out of his side. Uncertain as to how to achieve the shot with computer graphics, Muren had considered physical solutions — such as a torso made out of gelatin — before finally hitting upon an unusual idea. “Jim had shot a reference plate of *Robert* for us,” Muren related. “The reference footage showed *Robert* with a bar through his body, which he then pulled out of his side. Of course, the bar was actually a hoop that fitted up to his side, with a piece of bar extending out in both the front and the back. But I began to think that maybe we could make this reference plate work for the shot. We started by painting out, frame by frame, the hoop which ran between the two pieces of the bar, using Photoshop. Then, Doug Smythe match-modeled the section of *Robert*’s torso from which the bar was removed. Finally, we computer-modeled a piece of bar to fill in the space where the hoop had been and blended it with the two bar sections in the original reference plate which extended out on either side.” A subtle rippling effect was also added to the area surrounding the bar.

Armed with the steel rod, the T-1000 escalates his assault on the *Terminator*, finally impaling him with the rod and pinning him to the grated flooring of the steel mill. A final stage articulated *Terminator* puppet was used effectively in the sequence. Seen first was a cheated angle of the rod going through Schwarzenegger’s body. Then there was a closeup of the rod actually penetrating the puppet. Mechanical effects crew member Craig Caton built the puppet with radio-controlled leg articulation to create a crawling action as the *Terminator* attempts to free himself. “It had full leg motion,” said Richard Landon. “The knees bent and the legs flexed forward and back at the hips. Either leg could also spread side to side. The arms were puppeteered with rods. The head had nineteen servos in it to power the various articulations of the face.”

For a moment, it seems as if the *Terminator* has been beaten. But then a closeup of his face reveals a dim glow in his mechanical eye. There follows a Termovision shot displaying a diagram of the cyborg’s circuitry. “In the Termovision shot,” said Van Ling, “you see him reroute his power to an auxiliary source. It explains how he manages to muster up the reserve power for the end of the battle. We had also added another Termovision shot to an earlier part of the sequence to show the *Terminator* tracking the



Unable to regain his balance, the T-1000 tumbles backward into a vat of molten steel where he begins to metamorphose into the many forms he had assumed in his unsuccessful attempt to kill John Connor. All of the actors involved were photographed in the molten steel — actually a pool of backlit water covered with aerated mineral oil — and the resulting plate material was delivered to ILM where the characters were made to morph from one to the other, with various metal man stages in between. Shot supervisor Stefen Fangmeier previews one of the shots on his monitor.



T-1000 through steam in the steel mill. The shot indicates that he can't track through the heat of the steam with his infrared — which was important in establishing how the T-1000 was able to sneak up on him."

As the superheated steel pit dissolves her, this for once is a kind of Terminatorism that Sarah to lower him into the steel pit. Flame elements marking his absorption into the molten metal were added optically by Fantasy II.

With the *Terminator* presumably out of the way, the T-1000 — in a ploy to draw John out of hiding — transforms himself into a clone of Sarah. The real Sarah — actually Hamilton's twin sister, Leslie — confronts the T-1000 impostor, firing a shot as the machine returns to its cop form. A direct morfin'g effect — the only one in the film that did not include an intermediate metal man stage — was required for the transformation. "We had two live-action elements — Linda Hamilton as the T-1000 and Robert Patrick as the T-1000 — and we had to morf between them," said Doug Smythe. "The most difficult thing was trying to find a cut in all of the takes where Linda's ending position and Robert's starting position were similar enough to do a morf between them. The two actors were extracted from the background — using traditional hand-drawn articulate mattes — and then morfed. We also had a clean plate with neither actor in it, and I spent two or three weeks coming up with a single background plate that would work for the duration of the shot. I had to color correct the three backgrounds — the one with Linda, the one with Robert, and the clean one — so that they would match. Finally I came up with a sequence of matching backgrounds into which I could composite the morfed element."

Sarah and the T-1000 face each other in what seems certain to be Sarah's last living moment. The revived *Terminator*, however, appears in time to fire a grenade into the T-1000's stomach, blowing him open and causing him to stumble back and fall into the molten steel pit. Three full-sized 'Pretzel Man' puppets — sculpted by Chris Swift and Andy Schoneberg — were required for the sequence. The first was a foam rubber mockup of Robert Patrick, sculpted in a splayed-open configuration and then folded in on itself into a roughly human form. "Evan Brainard made the piece," stated Mahan. "After it was folded, it was held together with trip pins and springs. It had a big fold in the middle, but that was all right because it was filmed in smoke and it was a very quick cut." The first stage puppet was also fitted with a pneumatic ram to drive the head upward and around as the body sprang open.

Much more articulation was required for the following shots which show the dazed T-1000 floundering at the edge of the pit. A second stage puppet was constructed and mechanized by Brainard. "The second stage puppet was basically standing on two gimbals," said Landon. "There was a gimbal mount in each ankle and then a puppeteering rod coming straight down through the leg from the knee, which provided the gross body motion. There was a secondary linkage which picked up a point just behind the knee, and that drove the upper thigh area. Then the hips were joined with a bar that had a pivot on either side, and that provided the hip movement." Through the gimbals and rods, puppeteers stationed below the set were able to provide the gross body movement of the figure. The head — which had both jaw and eye movement — was radio-controlled. There was also a cable-actuated rotary action that spun the head back towards camera for one final stunned look before it tumbles into the pit. The third puppet, which had no articulations at all, was a simple foam construct with a thirty-five-pound weight in the back end to expedite its fall into the molten steel.

Pretzel Man was the last of the major animatronic effects to be featured in the film. Though the effort to more perfectly duplicate nature in steel and foam rubber goes on, Stan Winston is justifiably pleased with the quality of his team's work in *Terminator 2*. "It is one thing to make a puppet that looks good in the shop," Winston commented, "but it is quite another to actually make it look good in the film. Jim Cameron used the puppets seamlessly — which is what I always hope for. In fact, when we would call the lab the day after shooting and ask how the puppet shots looked, I always got the same question: 'What puppet?' Even on shots where it was pretty obvious that there was an effect because there was a hole through a guy's head as big as a soccer ball, I still heard: 'What puppet?' I considered that to be a wonderful response to the work."

With the T-1000's fall into the pit, there begins a series of shots depicting strange permutations of the character as he melts into the diluting molten metal. Conceptualizing and executing the death pit sequence was one of the most challenging aspects of the entire show for ILM. "The character goes through several transformations in his chrome state," said Doug Chiang, "and one of the most difficult things was trying to find a look for that that would read. The T-1000 is a very reflective creature — and in white-hot molten steel that white-hot light would have actually blown him out. So we had to come up with a stylized look for the chrome material and how it would dissipate in the pool of molten steel. I did a series of color key frames — concept art for each frame almost — showing the dissipation and how the character actually changed from chrome to a slightly duller material to, finally, its melting form,"

Unlike the other transformations — which were very specifically storyboarded by the production — ILM was given somewhat free rein in developing concepts for the death pit scene. Though the computer graphics team came up with a variety of ambitious ideas, the sequence was ultimately toned down to a series of morf effects achieved with both animation and live-action elements. "The first two shots in the death sequence were relatively straightforward morfs," said Smythe. "In the first one, the face of the T-1000 sort of smears as it changes from Robert Patrick to Janelle. There is an interesting stretching effect between those two images, which was a painting done by Doug Chiang. The next shot was a three-way morf where it



By the end of the film, Arnold Schwarzenegger required hours in the makeup chair prior to each day's shoot. The final stage makeup — after his character's drubbing by the T-1000 — entailed extensive facial appliances, a mechanical eye and a prosthetic chest piece. Shane Mahan attaches a severed mechanical arm to the actor who had to keep his own arm pressed behind his back.



On a platform overlooking the molten steel pit, James Cameron works with Schwarzenegger and Edward Furlong as the two rehearse the poignant farewell scene between young John Connor and his cyborg protector.

went from Janelle to Lewis the guard to the chrome version of Robert Patrick.” The actors involved had been given specific choreography and were filmed thrashing around in the molten steel pit at the mill site. To place the chrome character in the death pit, however, additional plate material was required. “Obviously, there was no photography showing the chrome cop interacting with the pool of molten steel,” noted Dippe, “so we made our own little death pit and photographed splashes to composite over our CG element of the chrome cop.” With foreground smoke elements and a heat ripple effect, the complex sequence had as many as thirty separate elements that needed to be composited together. And though the sequence had been shot locked-off, a slight camera move was added to the shots. “We blew the plate up about five percent and then did a two-dimensional camera move on it, as if the camera was hand-held. It was not like an intentional camera move — but rather like the subtle movement that really happens when a cameraman is holding a camera and shooting something. Doing that made the shot much more dynamic.”

The T-1000 is finally absorbed into the molten steel and is effectively terminated. Though the immediate threat is now gone, the *Terminator* realizes that his own very existence threatens the future of mankind. In an act which reveals his remarkably raised consciousness, the cyborg sacrifices himself to the pit of molten steel. The original plan had been to shoot some sort of practical fire simulation on the *Terminator* during his live-action descent into the mineral oil death pit. When no viable practical solution was found, however, Fantasy II was called upon to produce fire elements which could be composited into the shots optically. “We had to make many, many fire elements,” noted Gene Warren, “although it looks like there is only one. The first shot, for example, was actually six separate fire elements laid on top of each other. We shot the elements on a *Terminator* puppet — one of Stan Winston’s full-sized dummies — and then we had to match the movement in the live-action and track the fire so that it moved in exact sync with Arnold. Because we were shooting the fire on a physical object that was the same shape as the live-action, we were able to line everything up exactly with clips. The puppet was painted black and we shot the fire moving up it. In a couple of shots we had the puppet hooked up to our go-motion rig so we could get the puppet moving down at the right speed and the camera tilting at the right speed. We were able to get pretty close to the live-action; but because it didn’t fit perfectly, it had to be tracked and rotoed and then we added some smoke elements to tie it all in. Once we got the tracking right, we made an interpositive of the fire. Next we made holdout mattes — combination ones — because we couldn’t just burn in the fire on this kind of thing. Most of the time we need low-density mattes to make optical fire look like it really belongs. Then, if we had six fire elements, we had to combine all those mattes together. In a couple of shots there was smoke blowing across Arnold. On those, we had to pull mattes from the footage itself. Then, when we printed in the holdouts, we ran those smoke elements to hold back the holdouts. These shots *had* to look good. They were the last five shots of the *Terminator* — and if they had looked stupid, then a very important moment in the film would have been ruined.”

The moment was enhanced further with Termovision shots which illustrated the *Terminator*’s point of view as his life systems shut down. “The first Termovision shot had glitching to show that he was malfunctioning,” noted Van Ling. “We ran into a number of difficulties, since we were in the digital realm, trying to figure out how to create what were essentially analog sync loss hits. You can animate static and glitches, but it always looks fake. What we found worked best was to take the

shot from the computer with some minor glitching, transfer it to video, then shoot it off the screen while futzing with the connections. That gave us exactly the look we wanted — and the fact that it was at a lower resolution didn't hurt the shot because at this point the *Terminator* was supposed to be on lower power anyway." The final Termovision shot shows a collapse of the image into a little video dot which then disappears. "It's sort of like, 'Game over, man.' We witness his actual death, rather than just seeing him sink into the pit — which was much more dramatically satisfying."

Postproduction work on *Terminator 2* continued until just days before the film's release. The computer team at ILM took satisfaction in delivering their final shot a full day early. It was the culmination of a year's worth of learning and pushing the limits of computer graphics technology. "At the beginning of this project," said Steve Williams, "we were all saying, 'Let's shoot for doing the first computer generated man' — and we almost got there with a chrome version of a real person. The intention for the future is to go all the way, and that will happen — most likely here. Imagine having an actor that you don't have to pay points to! We're *that* close to being able to do it. There's a real revolution in CG technology now — and *Terminator 2* kicked it off."

"I have felt very strongly that ILM should be the place to do this work," stated Dennis Muren. "We have been able to really focus on computer graphics, especially since *The Abyss*. And George Lucas has really supported it. All the way back to the second *Star Wars* movie, George said that digital was the way things were going to go. We've been doing this since the early eighties, and there have been a lot of changes in the technology. For one thing, it is quite a bit faster; therefore it is less expensive. We have programs now — like looping on the monitor so you can look at a full-color image over and over again — which are very important in getting these images to really work. You have to be able to look at them and react and change them over and over again until you've got your shot. Before this, the turnaround time was just too slow. We could have done almost everything we did for *Terminator 2* five years ago — but it would have taken us five years to do it!"

Terminator 2 opened the Fourth of July weekend with its own brand of fireworks — Cameron-style. Favorable reviews and blockbuster grosses suggested that a *Terminator 3* would be enthusiastically received, if offered. Arnold Schwarzenegger fueled the fire by proclaiming that he was more than ready for a third outing — but only with James Cameron at the helm. For his part, Cameron seems satisfied that the story he first drafted nearly a decade ago has been brought to its fitting conclusion. "*Terminator 2* does it for me. Not only does this story change the future, it unmakes the future that made both films possible — so it's a closed loop. As far as I'm concerned, *Terminator 2* answers all the questions. But you can make a long list of filmmakers who have said: 'No, this is it. This is all I have to say on the subject.' And then, sheepishly, five years later they're skulking about working on another sequel."

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